ИЗВЕСТИЯ
АКАДЕМИИ НАУК СССР
СЕРИЯ ГЕОЛОГИЧЕСКАЯ

IZVESTIYA AKAD. NAUK SSSR
SERIYA GEOLOGICHESKAYA

1960 No. 5, May

CONTENTS

CHRONICLE

TWENTY-FIFTH YEAR OF PUBLICATION

Technical Editor - V. Ya. Karasev

T-05410 Approved for printing April 21, 1960
Circulation - 3, 425 copies. Order 3117

Paper size 70 x 108 | Paper 4 | Printing sheets 10. 96 + 3 ins. | Publ. sheets 13. 5

Second printing office of the USSR Academy of Sciences Publishing House.
Moscow, Subinskiy per. 10.

PARAGENESIS OF SEDIMENTARY AND VOLCANOGENIC ROCKS AND FORMATIONS[1]

by

N. S. SHATSKIY

The article discusses certain types of paragenesis of sedimentary and volcanogenic formations. Types of members of sedimentary associations are distinguished and described and the succession of their spatial distribution within formations is analyzed.

The importance of paragenesis in distinguishing sedimentary formations is demonstrated in the example of carbonate platform formations.

* * * * *

TAXONOMIC UNITS OF STRATIFIED MINERAL MASSES

It has long been known that stratified rocks, sedimentary and volcanogenic, are not random in occurrence: they form natural, clearly distinguishable complexes and combinations. The beginnings of this knowledge are lost in antiquity, in a time when these simple regularities characterizing the simultaneous occurrence of ores and rocks were already applied in mineral prospecting and exploitation.

Only recently, however, have geological associations begun to enter into the scientific procedures of modern geology. It is noteworthy that these ideas came into use in geology in various countries at almost the same time: P. Niggli and E. Vegmann in Switzerland, S. Bubnoff in Germany, L. Slos and F. Pettijohn in the United States, and others in France, etc. In the U.S.S.R. this group of problems has also been discussed for a long time in the literature (by A. D. Arkhangel'skiy and N.S. Shatskiy—[1-3, 19]), but these ideas were developed quite extensively after World War II in conjunction with the study of formations (M.S. Shvetsov, L.B. Rukhin, V.I. Popov, N.P. Kheraskov, V. Ye. Khain, V.V. Belousov and many others). As always in such cases, early investigators based their study of formations on different scientific premises and the concept of "formation" itself was variously defined.

It now appears to me that the most accurate definition of the term is that which I proposed long ago. This definition may now be given in brief as follows: sedimentary formations are natural complexes (associations) of rocks, the individual members of which (rocks, bands of rocks, suites, deposits) are paragenetically interrelated both laterally and in vertical stratigraphic succession.

Perhaps this is an extremely terse, purely morphological definition, but it appears to be the most correct, since it contains no hypothetical premises. Nevertheless it contains the elements required for distinguishing formations.

Formations are paragenetically related rocks; hence each type is distinguished by its particular paragenesis as well as by the composition of its members (rocks, bands and deposits) and the spatial relationships between them. Although there are convergences of formational parageneses (external resemblances between formations belonging to extremely different, and sometimes opposite groups), a thorough petrographic study of the rocks of such associations will readily discover the essence of this similarity.

Formations are the highest unit in the hierarchy of systematic categories of rock classification. In fact, in the stratified (chiefly sedimentary) mineral masses of the earth's crust the following taxonomic units may be distinguished:

A. Sedimentary rocks of the stratified series the simplest elementary types of sedimentary formations. The primary criterion of this taxonomic category in lithology is its chemical and mineral composition and structure, reflecting the conditions of its formation (for example, terrigenous and carbonate rocks, silicites, etc.).

B. Associations of sedimentary rocks. In these complexes the rock is not considered

[1]Paragenezy osadochnykh i vulkanogennykh porod i formatsii.

separately, as an elementary unit of taxonomy, but as a member of an assemblage; thus the object of study here is the association itself.

Associations of sedimentary rocks are divided into two essentially different natural groups:

1) Deposits of different type and origin. Essentially, these are the associations known as lithological-genetic complexes or genetic types of deposits, in the sense in which the term was first proposed by A. P. Pavlov. These complexes thus include, for example, such deposits as the alluvial, glacial, proluvial, lacustrine, littoral-marine, pelagic, deltaic, etc. (that is, associations whose classification reflects the geographic conditions or physical features of past geologic periods). In any case, our knowledge in this field is extremely great, as can be seen from the superb recently published two-volume reference book on geographic conditions of sedimentation written by D. V. Nalivkin [12].

In the nomenclature, classification and methods of distinguishing sedimentary associations of this category, a large role has been played up to now by the prevailing "actualistic" views of the history of the earth's crust. As a result the genetic types of continental (subaerial) deposits, as deposits which are more easily subject to "actualistic" analysis, have been much better studied than the marine and oceanic associations of this type. The introduction of modern techniques in oceanography, particularly the methods of visual submarine observations and photography, may sharply change our conception of the subaqueous conditions of formation of sediments and of the deposits themselves.

2) Formations are the largest taxonomic units of the sedimentary mantle. They are natural complex associations, the members of which are sedimentary rocks and deposits of different type and origin. The distinctive features of these associations are related to corresponding features in the development of the major tectonic structures of the earth's crust; thus in the classification of formations the principal subdivisions are distinguished according to tectonic principles (platform formations, geosynclinal formations, etc.). Formations are also characterized by the fact that certain of these stratified masses include not only sedimentary rocks and deposits but also volcanites, lavas and their pyroclastic derivatives. Only in the taxonomic units of this category can questions of the effect of volcanic processes on sedimentary formation be attacked and solved.

Complexity of structure and composition are characteristic of formations; this is reflected, in particular, in the English term "assemblage", which is defined in the American literature as "complexes of sedimentary rock" and is close to our "formations" [10], or, in P. Niggli's usage for similar formations, to the term "Gesteinsassociation" [34].

Thus each higher taxonomic category is, as is to be expected, distinguished by greater complexity and broader content.

It is well known that formations of the major tectonic units (for example, platforms and various geosynclines form their characteristic series, their parageneses, in each era constantly repeating the folds occurring under similar tectonic conditions (that is, they form an aggregation of a higher order than formation). This is the paragenesis of formations.

The almost complete identity of these types of geological formations is characteristic not only of the post-Riphaean orogenic cycles. E. Vegmann and S. Bubnoff have noted the similarity between the molasse-flysch-penninicum series of the Alps and analogous complexes of the Variscian deposits of Central Europe, and the Precambrian homologous formations of Kareliya and Jotnia, the "oldest red sandstone" as described by J. J. Sederholm. Such a term might be proposed for these associations, which are, as it were, of higher order than formations. It appears to me to be more correct, however, as I have done, to refer to these simply as formation series, implying thereby both vertical series of formations (that is, their sequence in time) and lateral series comprising formations of alternating facies.

Types of formation series are distinguished according to their tectonic position, so that there is no substantial difference in principle in distinguishing and classifying formations and formation series. On the other hand, these differ sharply from genetic types of deposits, which are distinguished according to paleogeographic features, and from unit rocks, the definition of which is based on structural features and chemical composition.

These considerations lead us to conclude that in the stratified mineral masses of the earth's crust it is necessary and sufficient to distinguish the abovementioned taxonomic units: rocks, deposits, of various genetic types, formations and formation series.[2]

---

[2]In discussing the terminology of sedimentary masses it is necessary to remark briefly on the sense in which the term "facies" is used in this article. "Facies" is here understood in the conventional geological sense. Thus the Donets formation (of the Middle and Upper Carboniferous in the Donets Basin) is a facies of a carbonate formation of the Middle and Upper Coal Measures Series of the Moscow Basin; the sandy deposits of the lanceolate zone on the northern margin of the Donets Basin are facies of the white chalky marls of the same age in the Kupyansk region; finally, the sedimentary Viséan

TYPES OF PARAGENETIC RELATIONSHIPS BETWEEN ROCKS OF SEDIMENTARY FORMATIONS

Despite the substantial differences in interpretation of the meaning of the term formation and the types of formations, as well as the principles of their distinction and classification, almost all investigators agree that the rocks comprising formations are paragenetically related, that formations are thus not random accumulations of rock but are completely distinct associations forming definite natural historical bodies. Hence it appears that the current formulation of the paragenetic relationships between members of formations is not simple enough, and that it will be necessary to undertake a detailed study of these relationships to determine their nature. This article will attempt to present some information concerning the parageneses of formations.

The paragenesis of sedimentary and volcanogenic rocks comprising formations is expressed in the fact that in the sedimentary mantle there are regularly and distinctly repeated associations of rocks, first in the form of facies series and then as facies combinations.

By facies series is meant a series of rocks of the same age with facies alternating in the lateral direction. By facies combination is meant an accumulation of rocks of contiguous facies associated by joint occurrence in a formation and not by mutual exchange owing to displacement, as in a facies series. It is my opinion that in identifying these two natural groups within associations and in further distinguishing within them the various types of facies series and combinations, we shall be able to approach the extremely important problems of natural classification of formations, their internal structure and, finally, the origin of sedimentary associations. Let us discuss briefly each of the abovementioned groups comprising formation parageneses.

Facies Series

There are at this time relatively few known facies series which have been distinguished on the basis of immediate stratigraphic and lithological observations in the field. But I believe that the total number of typical facies series in the sedimentary parageneses of the earth's crust is probably relatively small—not more than several score for the last new megachron. These series are most easily located among carbonate and halogenic deposits of platform formations, the rocks of which have been thoroughly described in papers by M.S. Shvetsov, I.V. Khvorova, G. I. Teodorovich, N.N. Forsh and others. Exceptionally valuable material on this group of facies series has been obtained in connection with core samples from exploratory test wells on the Russian platform. For the general characterization of the possible variations and possible extent of facies displacements in the rocks of this group let us consider some of the better known carbonate-halogen series.

Of these, the most common and apparently widespread in occurrence are:

1. [Gypsum dolomite → dolomite → dolomitic limestone → limestone] [3]

2. [Dolomitic limestone → limestone → dolomite]

3. [Limestone → dolomite → limestone (freshwater)]

4. [Limestone → dolomite → magnesite]

5. [(Salt) → gypsum (anhydrite) → gypsum dolomite → dolomite (pelitic, oölitic) → "spotty" dolomite → limestone (fine-grained)].

In these series the arrows indicate the direction of facies changes from the central portions of the formation to the periphery; a simple line indicates that the direction of this change is not determined or evident.

The first of the above-listed series in such complete form is well established in the carbonate formation of the Okskaya suite of the Russian platform. In his remarkable work, "The History of the Moscow Coal Basin in the Dinantian Epoch" [26], M.S. Shvetsov has described in detail the end member of this series. It is represented in the south of the Moscow syneclise by various extremely pure marine limestones of chemical and organic origin, the modern analogs of which M.S. Shvetsov sees in the limestone deposits of

---

limestone (in the southern part of the Moscow syneclise) is a facies of a grey dolomite of the same age in the central part of the basin; the continental Oligocene deposits of the Urals represent a facies of the marine formations of this age in the Mangyshlak region. In other words, both rock units and deposits of various genetic types and formations, and even formation series, may be facies of other rocks, deposits, formations and formation series; that is, all these sedimentary formations will be referred to as facies when they are considered in the context of other formations of the same age and level of classification.

The use of the term facies in an absolute sense as indicating the conditions of formation of sedimentary rocks and strata will be avoided, for in this case the term facies is always easily replaced by more obvious terms—deposits, sediments, etc. When a term is easily replaced by a simpler term, it is an indication that the first term is superfluous. In this way it is easily seen that the term facies in the second sense is not required.

[3] For convenience in reading I have placed "series" in square brackets.

Florida and the Bahamas. To the north and northeast of the southern flank of the Moscow syneclise the pure limestones are replaced by limestone and dolomite facies and, finally, in the axial portion, by a uniform stratum of dolomites ranging in color from grey and brown to almost black. In places the dolomites are gypsiferous [8]. To the east, in the vicinity of the Urals and on the western slopes of the range the dolomites and dolomitized limestones are again replaced by limestone facies. Thus in the facies series described here the gypsiferous dolomites and dark dolomites, almost devoid of fauna and comprising the central portion of the formation, toward the periphery are laterally and successively displaced by dolomitized limestones.

This multi-member series is extremely widespread in nature, and there is basis for believing (in regard to the Lower Cambrian of the Siberian platform) that it may be expanded in the interior of the formation by such a member as gypsum (anhydrite) and even perhaps rock salt (although the latter appears somewhat less likely). I am of the opinion that the salt may also belong to a special, distinctive facies series.

It is quite possible that in the facies displacements of the Okskaya suite, from the gypsiferous dolomites to the pure limestones there exists a complete facies series, since west of Moscow and Pestov, where in the Okskaya strata there occur thick allophilic (this term will be explained below) terrigenous deposits, the carbonate beds are also represented only by limestones.

Essentially different is the case of wedging out of the carbonate series, for example, in certain strata of the Serpukhov stage and in the Middle Carboniferous, in the Kashir stratum. As was first noted by M. S. Shvetsov [26] and then described in detail by I. V. Khvorova [18], in these deposits among the parent rocks of the periphery of the formation the carbonate rocks are often represented not by limestones, as in the Okskaya strata, but by dolomites which are replaced toward the central portion first by limestones and then by dolomitized varieties. I do not know whether or not I. V. Khvorova is correct in her explanation of the conditions of sedimentation of dolomites associated with the wedging out allophilic terrigenous layers, but I believe it is only of secondary importance that this series [dolomitic limestone → limestone → dolomite] is an independent type of facies displacement and is not an end member of the first of the series described.

Close to, if not identical to, the "zveno of the last two members is the [limestone-dolomite] series recently distinguished by A. L. Yanshin (verbal communication) in the Middle Sarmation carbonate strata of Ustyurt. In this case it is seen that replacement of the limestones by dolomites along the periphery of the formation is due to freshening of the sea water in the littoral portions of the basin. According to A. I. Osipov [13], in the Alayskiy and Turkestan stages of the Paleogene in Fergana there may be an enlargement of the facies series by still another peripheral member, namely freshwater limestones. This is the third of the above-mentioned facies series.

It is not certain that the same explanation applies to the extremely complex, sometimes grotesque interrelationships between dolomites and limestones in the very thick carbonate rocks of the Late Precambrian, forming a series of indeterminate direction [limestone → dolomite → magnesite]. In any case this series differs markedly from analogous chains in the Paleozoic carbonate strata in that it is wholly lacking in gypsum-anhydrite.

On of the examples of the most complete chemogenic series was studied in detail and described by N. N. Forsh in his excellent monograph on the Ufa suite in the Kazanian stage of the Volga-Urals region [17]. In the Kazanian deposits of the Transvolga region rock salt constitutes the central portion of a vast lagoonal lens in the Orenburg area. Gypsum not only covers and underlies the salt, but also extends far along the periphery, replacing the salt facies. N. N. Forsh was able to establish that the gypsum layers are deposits of this same great salt-forming basin; their beds extend over vast distances. Thus, according to his data, the main beds of gypsum in the Kazan region extend to Samar Luka and continue far to the south. A characteristic feature is the transition from gypsum to dolomite through fine-grained and thin-layered dolomites containing layers of gypsum and a mass of gypsum concretions. "Apparently," writes N. N. Forsh, "the deposition of gypsum and dolomite at times occurred alternately and at other times simultaneously." In the Middle Volga region these gypsum dolomites form clear, well preserved layers, but in the Kazan region the gypsum disappears and they change to dark fine-grained, thin-layered, often lamellar dolomites with marine fauna.

The dolomites form distinct layers in the Kazanian stage. On the eastern periphery of the Upper Kazanian basin there is a clear transition from these fine-grained dolomites into limestones of the same structure. In the Lower Kazanian lagoonal deposits fine-grained barren dolomites are also well developed. As in the Upper Kazanian beds, "at a relatively short distance these dolomites change on one side into gypsiferous dolomites and on the other side into limestones and marls." "In their time of deposition they correspond to the gypsiferous dolomites and barren fine-grained dolomites of the vast Upper Kazanian lagoonal basin, but they appear only at its eastern extremity where the influx of fresh waters from the Urals had a freshening influence on the brackish waters of

this lagoon, which inhibited the precipitation of gypsum and $MgCO_3$ and facilitated the precipitation of limestone sediment. In many cases I [N.N. Forsh] was able to trace the gradual transition of the Upper Kazanian dolomites into these limestones" [17].

In this example the facies replacements [salt - gypsum → dolomite → limestone] are explained by the freshening effect of river waters. The river arteries both of the Urals and of the more western portions of the Russian platform poured their fresh waters into the eastern saliniferous lagoon of the Lower Kazanian stage and into the vast Upper Kazanian salt-forming basin. The deposits of the latter, however, must not be considered to be deposits of an isolated lagoon cut off from the open sea. As may be seen from stratigraphic and paleogeographic data, the entire vast salt-forming basin of the Konkhifurovian epoch arose on the site of the marine basins of the Upper Paleozoic. The halogenic deposits of the latter, like other large formations of evaporites, were formed not under the influence of a partial local isolation of a lagoon from the sea by a bar, but as the result of a prolonged process of concentration of sea water in vast basins occurring in the process of tectonic morphogenesis.

We have discussed above only those facies series whose members are rocks of the carbonate and evaporite classes. One of the characteristics of these series is their great variability and instability, due primarily to the sharp reaction of sedimentation of this type to a change in the external paleogeographic and, consequently, the physiochemical conditions.

As an example of a contrasting, extremely stable and constant facies relationship let us discuss a two-member series:

6. [Glauconites → leptochlorite rocks].

This facies combination of glauconites with ferruginous oolites is well known. The lateral transition of rocks with ferruginous oolites into the glauconitic sands of the Upper Jurassic and Lower Cretaceous deposits of Central Russia and the Volga region was discussed in 1937 by G.I. Bushinskiy [6] and in 1938 by A.V. Kazakov [9]. They explained this type of facies replacement as being due to a change in depth of the basin and distance from the shore and, geochemically, to variations in the pH and temperature of the sea water. M. Solignac [36] has described a similar facies pair for the iron-ore deposits of Jebel'-el-Ank in Tunis. As in many other places in North Africa in the Eocene and Cretaceous deposits, the replacement of glauconites by oolitic iron ores is well known, whence M. Solignac assumes that the iron of the oolitic ore and the iron of the glauconite are of the same origin. Such displacement of chamoisite ores by glauconite rocks has been observed in the Upper Cretaceous deposits of the Ob' River region (Western Siberian platform — 25). Glauconites and chamoisitic oolites as a facies pair also form part of the parageneses of certain Paleozoic formations. For example, in the glauconitic limestone formations of the Ordovician in the Baltic region I. Bok [5] has described a "lenticular" stratum, which is represented as consisting of ferruginous oolites. Glauconite layers are rarely found together with chamoisitic rocks in the Upper Givetian carbonate-terrigenous and Lower Frasnian deposits of the central and southeastern portions of the Russian platform [11, 16].

The details of the processes whereby a given rock, such as glauconitite, is replaced by another of the same facies series (that is, oolitic iron ore) are not known; more accurately, I do not know of any description of such replacement. The facies relationship of the constituents of both components of the described series, however, is obvious. The occurrence, within certain strata (for example, in the Yegor'yev deposit) in the Upper Volga phosphoritic glauconite with Craspedites subditus, of ferruginous oolite grains indicates the possibility of gradual displacement of glauconitic rocks by chamoisitic rocks.

The two-member series [glauconitite → leptochloritic rock] occurs quite commonly, although they form strata of incomparably smaller thickness than the evaporite and carbonate series. I have emphasized this facies series because in the classical petrography of sedimentary rocks the glauconitites and leptochloritites belong to such different groups (clays — ferruginous rocks) that theoretically their mutual replacement may appear to be impossible.

The occurrence of facies series among clastic terrigenous rocks presents great difficulties. These consist chiefly in the fact that under natural conditions facies replacements are determined not only by a change in the granulometric composition of the rocks, but also by a change in their mineralogical composition, the characteristics of which were already implicit in the initial sharp differentiation at the stage of weathering of the parent rock. In the most general, purely abstract mechanical form a facies series of clastic terrigenous rocks is usually represented as a replacement of conglomerates and gravelites by sands, then by silts and finally by pelites (clays). Since the mechanical differentiation, however, if not entirely, is at least to a considerable degree a separation by "elutriation" of the already disintegrated and partially or entirely "decomposed" (by weathering) parent rock, these fractions will differ from one another both petrographically and mineralogically. This is particularly true of the smallest fraction — the "clays." If we exclude from the series the coarsest psephitic formations, we may present in the most generalized form a certain few

facies series of the clastic type; the best known of these are the following:

7. [A "kaolinic" weathering crust of granitoids and granite-gneiss formations → kaolinic (rock flour) sands and sandstones → quartz sands and sandstones → quartz silts _ kaolinic clays].

8. [An "arkosic" weathering crust of granitoids and granite gneisses → feldspathic arkoses → arkoses → feldspathic-quartz sandstones → feldspathic-quartz siltstones → principally hydromica ("polymictic"?) clays].

9. [Weathering crust (humid temperate climate?) of crystalline schists and extrusive sedimentary series → graywackes → "polymictic" (principally palgioclase) sandstones → "polimictic" sandstones → hydromica and chloritic ("polymiktic") clays and argillites].

As may be seen from the above three examples, the characteristics of facies series of clastic rocks depend not only (and, apparently, not as greatly) on the processes and conditions of transportation and deposition as on the composition of the parent formations whose destruction resulted in the various terrigenous deposits, and on the type of weathering leading to the destruction of these parent rocks.

The same parent rock of granitoid composition may yield the seventh facies series under one set of weathering conditions, and may produce the eighth facies series under other conditions. As an example of the seventh series we may cite the quartz sands and kaolins of the Poltavian stage, as well as the Upper Cretaceous rocks of the Vilyuy River basin.

The latter example is of particular interest. Here, along with the above rocks, there are extensive adjacent facies of bright white rock flour sands containing a considerable admixture of powdery kaolinite. In the latter rock, the elutriation of the kaolin from the quartz sand was not completed. From this facies series of the Linden formation one may easily see that the formation of kaolin clays is determined not by the differentiation of sediments according to their grain sizes, but occurs in the preceding phase of intensive weathering of the parent rock (probably granitoid).

It is quite likely, however, that there are quartz sands (sandstones) and even combinations [quartz sands, gray clays] of some other formation series, which are extremely close in their general petrographic features to the seventh series. It is possible, for example, that the famous [quartz white sands and sandstones, gray clays] of the Aptian deposits of the Moscow and Kaluga regions are not directly associated with the kaolin weathering crust of the granitoids and gneisses of the crystalline basement of the platform, but are the result from repeated redeposition of sands and sandstones of other composition, perhaps arkosic. The repeated weathering of these sands and the repeated elutriation with redeposition may explain the petrographic convergence of these formations with the rocks of the eighth series. I believe that this question may easily be answered by study of the heavy fractions of minerals that are particularly resistant to weathering. It is extremely probable that this is the origin of certain quartz sandstones associated with the feldspathic series of the sparagmite in Sweden and Norway (the Ringsaker quartzites) and the Riphaean deposits of the Russian platform.

W. Kennedy's recently published data [32] on arkoses indicate the extent to which redeposition and transportation within series of the psammitic and siltstone fractions may vary. For example, he showed that the granulites of the primary arkoses of the Torridonian series and the sparagmite contain up to 73.5% SiO_2. In the reworked and redeposited (more southern) granulites (quartz granulites) the SiO_2 content reaches 82-83%. For the sake of comparison it should be pointed out that in pelites, which could be considered an extreme member of this series, the SiO_2 content cannot be greater than 50-65%. This marked difference in composition is understandable, for the fine fraction (less than 0.01 mm) contains all the clay minerals arising from the disintegration of feldspars and dark minerals in rocks of granitoid composition from which the arkoses originated.

Psammitic and aleuritic varieties may always be regarded as facies replacements of the rocks of a single series; conversely, the pelitic varieties sometimes differ so sharply from the first two in their mineral composition that they are not members of the facies series, but rather forms part of the corresponding facies combinations.

The mechanics of the facies transition from some clastic terrigenous rocks to others are not very well known. This subject has been investigated in greatest detail by T.N. Davydova and Ts.L. Gol'dshteyn [8] in the case of continental terrigenous deposits. In their special and extremely detailed stratigraphic studies of the coal-bearing series of the Burein Basin they were able to make repeated direct observations of the gradual lateral gradation of cross-bedded polymict sandstones into an alternation of sandstones, fine-grained siltstones, argillites and beyond into a complex of bedded siltstones and dark-colored argillites.

The existing facts attest to the presence of three of the abovementioned facies series of terrigenous deposits (the seventh, eighth and ninth) and, on the other hand, indicate the impossibility of their being combined into a single series — from graywackes to orthoquartzites. The distribution of these series within formations also

tests to the impossibility of such a combina-on, since each of these series is associated ith particular tectonic conditions and struc-ires.

The first observations of the affinity of quartz-es, arkoses and graywackes for definite tec-nic regions and structures were made by M. . Shvetsov [27]; these ideas were later devel-ped in the United States by P. Krynin and par-cularly by F. Pettijohn [35]. In general both iese geologists, as well as many before them, onsidered graywackes to be characteristic of ie geosynclinal stage of tectonic development, rkoses of the orogenic stage and quartzites of ie post-orogenic stage of peneplanation. In iese ideas there is much that is correct and ng accepted; it is not certain, however, that iis association of rocks with structural condi-ons applies everywhere. It appears to the resent writer that these relationships may est be discerned in the distribution of terri-enous rocks within the facies series of vari-is groups of formations.

It is appropriate to conclude these brief re-iarks on the facies series of terrigenous rocks ith three observations on the number of clastic icies series, on the distinctive features of the xtreme pelitic members of these series and, bove all, on the influence of climatic conditions n the types of clastic rocks.

For example, it may easily be shown that nder identical tectonic conditions (for example, ver the territory of the Russian platform) from ranitoids and gneisses of the crystalline base-ient there may be formed both a [quartz sand quartz siltstone → kaolin] series and a com-etely different facies chain consisting of rkoses → felspathic sandstone → felspathic-iartz siltstone → polymictic (?) clays]. The iartz → kaolin series includes, for example, ie Poltava white sands and mottled kaolinic lays associated with the Ukrainian crystalline iassif, or the quartz sandstones and the kao-nic weathering crust of Riphaean age. On the ame tectonic structures are also developed the iick and extremely stable strata of arkoses and lymicitc sandstones, which are also of Ripha-an age. It has been demonstrated with suffi-ient exactness that formation of the kaolin eathering crust took place in a hot, humid opical climate, and that the arkoses, con-ersely, are associated with a thick weathering rust represented by thoroughly disintegrated ut little altered grains of the parent deposits. uchdisintegration and weathering are usually ssociated with a temperate climate.

It should be pointed out that in the first case, nder tropical conditions, thick masses (kaolins) ere formed. The composition of the pelitic omponents of the other series is not known with ny degree of accuracy; hence in these ex-mples they will tentatively be designated as polymictic clays. Many of them are apparently just such. It is quite likely that the pelites of these types are transformed during epigenesis into somewhat homogeneous clayey and argillitic varieties.

The three facies series (the seventh, eighth and ninth) which may be designated as the quartz-kaolinic, arkosic and graywacke represent, so to speak, the "pure" lines or "pure" facies series: the parent rocks from which they origi-nate, the bodies of granitoids and gneisses in the first two cases and the schistose volcano-genic formations in the third, were somewhat similar. There are apparently other "pure" series of clastic terrigenous rocks; however, I am unable to define them with accuracy. Gray-wackes and their derivatives in the geosynclinal zones are extremely common. Also frequently encountered are representatives of the arkosic series; conversely, representatives of the quartz-kaolinic series are encountered relatively rarely.

I believe, however, that the principal "pure" series are not the most widespread in the total volume of terrigenous series. Considerably more extensive in both types and total volumes are the hybrid series, which are combinations of the principal "pure" series or their rede-posited derivatives.

We have presented here only a few of the facies weries, not for the purpose of describing sedimentary associations but in order to char-acterize this type of paragenesis. There is no doubt that a thorough study of them will lead to a number of important generalizations, not only in the investigation of formations but also in the petrography of sedimentary rocks. They will be of particular significance in determining the origin of the principal types of sedimentary rocks and their natural classification.

Facies Combinations

In facies combinations the relationship be-tween the members of formations differs sub-stantially from that in facies series: whereas the latter are interrelated by direct replacement of one rock by another in a single stratum later-ally over a certain stratigraphic level of a single age (a stratum, packet, etc.), the members of facies combinations are related only by their simultaneous presence in one or another part of the formation, but need not be in the same bed or in direct contact with each other.

Facies combinations enter into the composi-tion of the members of parageneses of sedi-mentary associations no less frequently than facies series or the individual links in these series. These forms of contiguous facies mem-bers of formations and possible types of similar combinations, however, have been even less studied than facies series. It must also be

mentioned that as work advances in this field it may be shown that certain facies combinations belong to facies series. To characterize this type of paragenesis, let us present a few examples.

1. [Diatomites, volcanic ash]. I know of no cases in which diatomites and volcanic ash directly replace each other; theoretically, this is impossible. But the simultaneous and fairly close occurrence of these two is encountered quite frequently. For example, such a combination is characteristic of the Byurgut and Akhudag strata (Sarmatian-Meotian) of the so-called diatom beds of the Baku region and Kobystan [21]. Diatomites and volcanic ash are always present together in the Miocene formation of Monterey (California, [29]). This combination is also characteristic of the Upper Oligocene strata in the Carpathians, Rumania, the Antilles, etc. I believe that the moronites of the Spanish geologists in the Acquitainian and Burdigalian deposits of Southern Spain (the Northern Baetic Range) and the Balearic Islands belong to formations of this type [30]. The cause of this facies combination is apparent: the abundance of volcanic ash (of liparitic composition?) falling into the Tertiary seas and rapidly disintegrating in sea water created a favorable medium for the profuse development of diatom flora.

2. [Jaspers, pyroclasts, spilitic lavas] — the best example of a facies combination. For all the geological periods and all the interior zones of geosynclinal regions it is possible to produce a long list of examples of constant combinations of spilites and their tuffs with jaspers and their analogs and derivatives (lyddites, siliceous tuffs and schists, etc.). Of course, one cannot speak here of a facies replacement of these rocks, for the jaspers are probably a chemical deposit, the tuffs a clastic formation, and the lava a volcanic melt; nevertheless their joint occurrence is due to a common cause — a single magma chamber producing all these petrographically different rocks.

3. [Quartz sands → kaolinic clays, lignites] — another example of an extremely widespread combination. As examples we may also cite the bisque clays, quartz sands and lignites of the Moscow Basin; the white kaolinic clays and lignites of the Oligocene-Miocene continental deposits of the Bashkir Cisurals [26]; the white quartz sands, gray clays and thin seams of lignite of the Upper Cretaceous Linden suite the Vilyuy depression, and others.

This is a special type of combination: as stated above, [white kaolinic sands → quartz sands → kaolinic clays] are quite common, although they are a relatively infrequently encountered type of facies series. Hence the [quartzitic sands → kaolinic sands, brown (rock) coals] series is a complex facies conjugation consisting of a combination of a link in a facies series [quartz sands → kaolinic clays] with a simple paragenetic member [brown (rock) coal]. Such a complex conjugation is apparently not unique in the parageneses of sedimentary associations.

4. [Phosphorites, manganic rocks, chalcedony]. The paragenesis of phosphorites with manganic rocks was noted fifty years ago by L. de Launay [33]. Since that time numerous examples have been found of this combination, which is now one of the criteria in prospecting for manganese ores as well as phosphorites. This paragenesis is a typical example of a facies combination, since there can be no question of a replacement of phosphorites by manganese ores. The invariable presence of chalcedony (more accurately, siliceous rocks of various types) in this combination suggests that a low rate of sedimentation is one conditions (but not the only one) of the formation of rocks of this combination.

5. [Nodular phosphorites, glauconites]: another example of a facies combination, similar to the previous one. This combination is well known on the Russian platform and since the beginning of the present century has been interpreted as indicative of Mesozoic platform phosphorites. The invariable increase in the relative quantity of nodular phosphorites of this type as the thickness of the phosphorite-bearing formation decreases indicates that this occurrence, too, is associated with a low rate of sedimentation [20].

As follows from the above examples of facies combinations of sedimentary and volcanogenic rocks, this type of paragenesis differs from the parageneses of facies series, although it is possible that detailed lithologic investigation will require certain of them to be treated as facies series. I believe that in the future it will be possible to discover not only additional forms of parageneses, but also completely different types of parageneses and to produce a more detailed classification of paragenetic relationships.

In distinguishing and classifying types of facies series and combinations, in addition to tectonic (tectonic structures of motion and others) geomorphological and climatic conditions, it is necessary to consider th age of the sedimentary and sedimentary-volcanogenic associations. It is well known that many forms of facies combinations, like many rock associations, are characteristic of only certain stages in the development of the earth's crust. For example, in the deposits of the Riphaean and in pre-Riphaean formations, salts and gypsums are absent; conversely, in pre-Riphaean groups it is very typical to find such valuable and important facies combinations as ferrous quartzites of various types, etc. Along with the evolution of the earth's crust, there is also an evolution

of the sedimentary rocks and the facies combinations and series which the rocks constitute.

TYPES OF MEMBERS OF FORMATIONS AND THEIR DISTRIBUTION

Members of sedimentary formations form parageneses of a special type. These are not only "collections" of rocks, packets and sequences; nor are they merely a simultaneous occurrence thereof. Sedimentary associations in general and sedimentary formations in particular are characterized by the regular joint occurrence of their members. This regularity in formations is expressed in two directions: vertical (more accurately, stratigraphic) and lateral (which may also be termed facies).

The vertical regularity is reflected first in the successive stratigraphic distribution of various types of series and combinations of formation members, with a definite replacement of one type of rock by another, and is the result of a directional process of sedimentation in individual basins and geosynclines as well as the directional development of the earth's crust. Secondly, it is reflected in the fact that the general succession of stratification, the general order of replacement of individual facies series and combinations by others is disturbed by alternation or interstratification of identical or similar associations of members in the form of cycles, sequences, suites, etc. In geologic history there were successions of epochs in which the course of geological processes recurred, repeating the previous sequence of rocks (more accurately, not the previous sequence but geological conditions quite similar to those of the preceding epochs).

The types of "cycles" and rhythms and their related types of rock associations may differ. The appearance of some of them is explained by tectonic causes, by the general course of development of the major structural units, and by the presence of other sediments associated with seasonal variations in deposition. The classical works by A. D. Arkhangel'skiy [1, 2, 4] set forth with complete clarity the entire essence of the periodic changes in sedimentation on platforms and the regular changes to be observed there in the vertical succession of sedimentary rocks. On the Russian platform A. D. Arkhangel'skiy distinguished "sedimentary cycles", each of which begins with terrigenous-carbonate, (frequently glauconitic) associations; these are replaced upward by carbonate, limestone-dolomite formations, then by carbonate-anhydrite and halogenic formations and varicolored and red terrigenous formations. Of these sedimentary cycles the first, ending in the Devonian, and the second, ending in the Permian, are particularly characteristic.

These periodic or "cyclical" changes are caused by the orogenic, mountain-building movements of the Caledonian and Hercynian times. "The similarity here consists in the fact that at the boundary between the Permian and Carboniferous, as at the boundary between the Devonian and Silurian, in almost all geosynclines adjacent to the Eastern European platform, there arose mountain ranges, after which the platform itself was uplifted. The peculiarity of the Devonian period lies in the fact that the mountain building movements then occurred north, west and south of the platform, whereas the Urals geosyncline remained unaffected; consequently in the Devonian, at the eastern margin of the platform there were no mountain ranges [2, 4]. "Within individual formations, periodicity of sedimentary rock formation is an extremely prevalent phenomenon. Such periodicity or rhythmicality is particularly evident in such formations as the flysch, the "lenticular" clays or the thick coal-bearing strata of paralic basins. To one degree or another it may be found in most of the sedimentary suites of any age. In some cases ("lenticular" clays, certain "microfoliations" of marine deposits, certain deltaic deposits) fine rhythmicality is associated with climatic conditions and is explained by seasonal changes in sedimentation; in others the rhythmicality is the result of movement of the earth's surface caused by deformations of the earth's crust" [24].

Geologists encounter regular vertical successions very frequently, so that it is a constant object of their investigation. For the study of formations it is necessary to understand the great importance of vertical regularity in distinguishing the formations themselves.

Among geologists who specialize in facies analysis, particularly coal geologists, the postwar years have brought a wide acceptance of the concept of the correspondence of horizontal facies changes with the vertical succession of "facies"; this concept is usually known under the so-called Golovkinskiy-Val'ter principle. Since formations are paragenetic assemblages, it is, of course, natural that both the stratigraphic sequence and, in the same suites, the horizontal facies series should include very similar rocks, at times even in the same succession and combinations. This also leads to the concept of a repetition of the horizontal facies in the vertical stratigraphic sequence. In the spatial distribution of the members of formations, however, such regularity is the exception and is always encountered as a repetition of similar (but not identical) rocks.

The replacement of one formation by another vertically (in the stratigraphic sequence) and laterally (in the formation series) is easily established from the change in parageneses. Nevertheless the spatial interrelationships between formations may be different: in certain cases the formations replace one another gradually;

in others the delimitation between adjacent formations is extremely sharp and one association replaces another rapidly, and the "sharp" boundary may be stratigraphic or facies and not merely a tectonic boundary surface.

The sharpest delimiting surfaces between formations are those of the unconformable occurrence of strata and stratigraphic gaps. On the other hand, small local unconformities sometimes fail to disturb the paragenetic unity of the formations. For example, the small but in places numerous local unconformities and gaps in volcanogenic-sedimentary series are often intraformational.

With fully conformable occurrences and in the absence of stratigraphic gaps, in certain cases the boundaries may be quite sharp, as for example between the carbonate formation of the Lower Carboniferous and the Donets formation. Here the boundary is traced along the base of the Grabov zone (C_1g-C_1^2). In other cases the replacement of formations occurs quite gradually and the delimiting surface is to some degree tentative (for example, in the replacement of marine by continental molasse in the Karaganda Basin). The location of the boundary between these formations may only be established with an accuracy of several tens of meters [23].

To anticipate somewhat, it may be said that lateral (facies) boundaries are usually less clearly defined. In the paragenetic distinction of formations, however, these boundaries are no less reliable than the boundary surfaces between various facies complexes and facies and, consequently, they depend to a considerable degree on the gradualness or sharpness of the facies change.

In general, I believe that the boundary between adjacent formations is traced with the same degree of accuracy as a lithologic-stratigraphic boundary in paleontologically barren complexes. The identification of formations on the basis of field observations and the study of the changes from some parageneses to others is uniquely feasible. The distinction between formations on the basis of exaggerated, arbitrary classifications (climatic, tectonic) and other theoretical presuppositions, although it is apparently widespread, will hardly contribute to significant progress in the study of formations.

It is also necessary to stress the great practical importance of studying the vertical regularity in succession. It has been noted, for example, that the distribution of ores is strictly related to their vertical position in the formation. Some ores are, as a rule, encountered in the lower parts and others in the upper portions. As an example, in the ore beds of the jaspilite series the manganese ores always occur in the lowermost parts of these series. It appears that this phenomenon can be quite easily explained lithologically.

Finally, regularity in the lateral direction is reflected primarily in a definite facies change in which the individual members are arranged within the formation itself and the other (adjacent) formations are reflected in the given formation.

The distribution of the members within the formation itself is well defined by the basic facies series of the formation. In this respect formations may be divided roughly into two classes: symmetrical and asymmetrical. Perhaps this is an unfortunate choice of terms, for in general there are no wholly symmetrical formations. In certain (symmetrical) formations, however, the succession of members proceeds from the central part of the formation in all directions toward the periphery (for example, in the Carboniferous carbonate and Cretaceous formations); in others (assymetrical) the distribution of the members is clearly undirectional and from one side to the other a single series is often traced. Such, for example, in the European part of the U.S.S.R. are the red-colored formations of the Permian and the carbonate and saliniferous formations of the Upper Permian. The vast majority of geosynclinal formations and formations of marginal basins are of this class.

The division of formations into symmetrical and asymmetrical is, in its most general form, the geometric expression of the geological division of formations into autochthonous and allochthonous. These types are quite characteristic of platforms. "The autochthonous formations of platforms do not contain clastic deposits transported directly from adjacent folded structures. In the first place, these deposits are precipitated chemically or organogenically from the water of basins occupying the area of a platform at one time or another. These include salts, gypsums, anhydrites, limestones, dolomites, glauconitic rocks, gaizes, etc. Secondly, these are clastic formations resulting from the weathering and erosion of the rocks of those portions of the platform which, by one means or another, have been elevated above sea level (terrigenous formations — sands and sandstones, chiefly quartzose, with a small admixture of other stable minerals, clays, etc.). We shall also designate as allochthonous formations those which are the result of disintegration of marginal mountain structures and deposits of clastic sediments on the adjacent areas of the platform. As a rule, these are sands, sandstones (sometimes with thin layers of gravelites and conglomerates), siltstones, clays, argillites, etc. Over large areas of platforms, particularly in their interior areas, within the "allochthonous" formations (parent members) there appear individual interlayers (allophyllic members) of limestones,

marls and dolomites of autochthonous origin and, in regions farther from the soutce of transport, the allochthonous formations change into autochthonous. Such, for example, is the transition from the allochthonous formation of the Devonian red sandstone on the northwestern margin of the Russian platform (the "Old Red" formation) to the autochthonous carbonate and halogenic formation of the Upper Devonian in its eastern portion. A similar transition is known in the case of the deposits of the Kazanian stage in the opposite direction, from east to west [24].

The lateral influence of formations on one another is, as we have seen, reflected in the fact that certain members of the adjacent formations form long wedges extending far into the given formation. It is particularly necessary to stress that, as a result of uplift and erosion, of such adjacent formations these in-wedged members are often the only remnants. Thus within formations we distinguish "native" members (perhaps they are better referred to by the ancient Greek term parent members) and "foreign" or "neighboring" members, which should be termed "allophilic". The allophilic members, like the parent members, may form their own parageneses, but they influence the structure and even the composition of the adjacent formations. This is quite apparent from the effect of the terrigenous beds on the carbonate beds of the Kashirian beds.

The study of the allophilic members of formations is of great interest. It often happens that this is the only means of determining the nature of the association of the parent members. As an example, we may consider the single carbonate formation of N. M. Strakhov (C_1-C_3, Carboniferous system of the western part of the Russian platform) which has been divided into two natural formations from the genetic standpoint (C_2-C_3) and (C_1-C_1), particularly the composition and character of the allophilic terrigenous members on the western margin of the Carboniferous field.

In discussing the types and interrelationships of the individual rocks (or packets) in rock associations belonging to formations, for the sake of uniform terminology we use the following designations. We have already distinguished two types of members of formations, referring to them as "native" (parent) and "neighboring" (allophilic) members. These terms are used in cases where analysis leads to the conclusion of the nonhomogeneity of paragenesis (that is, the presence in the given formation of two or more paragenetic groups). One of these groups is usually wholly developed (parent) and the other, conversely, is strongly reduced and merely represented by isolated members ("foreign") of adjacent formations wedged into the given, or "parent" association. Thus these terms indicate the interrelationships between the individual parageneses composing a single rock association.

Along with distinction among members of the formations of the above two groups of rocks, it is worthwhile to divide the members of each formation into principal (chief, obligatory) and secondary (minor, optional). By principal rocks we mean those rocks which characterize the fundamental composition of formations as natural historical bodies; the term secondary indicates supplementary members. It is apparent that the chief members are always or almost always parent members, whereas the secondary members may include both allophilic and parent members.

As shown above, in the parageneses of rock associations those members which are most suitably termed facially contiguous are readily distinguished. Among these we distinguish, in the first place, facies links that is, members forming the individual links of facies series, or else the facies series as a whole, and, secondly, the facies combinations or individual members of facies combinations. Both may enter into the composition of parent, allophilic, principal and supplementary groups. It is of considerable interest note that among facially contiguous members it is sometimes possible to distinguish the replacing members; for example, glauconitic rocks replace ferruginous-oolitic rocks and, conversely, and even members of antagonistic character.

Thus it appears that along with the principal and secondary members of formations, it is necessary to distinguish parent and allophilic members, as well as types of facially contiguous members, thus making it possible to determine the lateral succession, and often the origin and nature, of formations.

IMPORTANCE OF THE STUDY OF PARAGENESES IN DISTINGUISHING FORMATIONS

It is best to discuss the significance of parageneses for establishing natural sedimentary and sedimentary-volcanogenic associations and, consequently, for distinguishing types of formations, on the basis of concrete examples, specifically the history of distinguishing carbonate platform formations on the Russian platform.

One of the first attempts to recognize and describe the carbonate formations of the Russian platform was made by N. M. Strakhov in 1951 [14]. The most characteristic type of carbonate formation N. M. Strakhov considered to be the "limestone-dolomite" formations, represented on the Russian platform by the Viséan deposits of the Middle and Upper Carboniferous. The thick series of Carboniferous limestones and

dolomites lying between the coal-bearing bed (C_1^n) at the base and the saliniferous-gypsiferous deposits of the Lower Permian at the top N. M. Strakhov thus considers possible to combine into a single formation, which was formed in his opinion, in a shallow "shelf" basin under the conditions of a predominantly arid climate. This limestone-dolomite formation on the Russian platform, according to Strakhov, is composed of detrital, silty and microgranular limestone accumulations among which are encountered thin but extremely characteristic biomorphic, coprolitic and oolitic limestones as well as clastic varieties (that is, limestone conglomerates, sands and sandstones, usually of subaqueous but occasionally of aeolian origin). These carbonate rocks also contain peculiar textures, indicating special conditions of deposition ("lagoonal" shoals, etc.) or else interruptions in sedimentation and erosion, or specific features of weathering of the underlying rock. In addition to the limestones, this formation also contains extensive dolomites, both primary and secondary, grading into very extensive dolomitized limestones.

If we regard the carbonate sequence of the Carboniferous system on the Russian platform as a single formation, we may observe a certain asymmetry within it. This is reflected in the fact that its western portion includes "more or less considerable interlayers of red clays and sometimes also of sands." In the eastern areas the latter rocks are extremely rare; here the section consists almost entirely of carbonate rocks."

It should be added that while N. M. Strakhov did not refer to the abovementioned limestone-dolomite formation, he did mention a formation of "writing chalk" quite similar to it. He considered the chalk formation to be a sort of supplement to the usual carbonate formations of platforms. The significant difference between the chalk formation and other platform carbonate formations (Carboniferous), according to N. M. Strakhov, "lies in the fact that the chalk is essentially a formation of the semi-pelagic type, whereas carbonate formations of platforms are usually typical shelf deposits, and even predominantly of the upper half or quarter of the shelf."

Large, compact agglomerations of rocks such as the carbonate deposits of the Russian platform were at that time (1951) designated by N. M. Strakhov as formations, but the uniform facies conditions and circumstances under which they were formed he designated as historical-geological landscapes. The landscape and conditions of deposition of the carbonate rocks of the limestone-dolomite formation were described by N. M. Strakhov as follows. In the Carboniferous period the Russian platform "had a tropical and subtropical climate, in which over a considerable portion of the platform area a zone of arid climate extended from the northwest to the southeast. It is very likely that much of the continent, located west of a sea, belonged to an arid zone. This fact, as well as the generally low elevation and lack of dissected relief on the continent even in that part which had a humid tropical climate, accounts for the extremely small amount of clastic material entering into the sea; this is also reflected in the negligible quantity of sand-clay sediments accumulated from C_1 to C_3.

At an earlier time (1951) I attempted to approach the question of the carbonate formations of the Russian platform from the standpoint of parageneses. This information has been published in part in my work on phosphorites [20].

Actually, the sequence of Carboniferous beds from the coal measures at the bottom to the Upper Carboniferous at the top in the Moscow Basin consists of limestones and dolomites. Upon superficial examination this sequence looks uniform and the special knowledge of a lithologist is required to identify all the varieties of limestones and dolomites mentioned above.

Nevertheless the geologist who, in seeking the solutionof practical and theoretical problems searches for definite parageneses of rocks will immediately distinguish in the carbonate sequence of the Moscow Basin not one (as does N. M. Strakhov) but two formations, which differ from one another in their parageneses.

In the upper of these, consisting of limestones and dolomites of the Moscovian and Uralian series, the paragenesis of the rocks is thoroughly defined. In addition to the numerous types of limestones and dolomites, this paragenesis includes carbonate red clays, red-brown, red and mottled sandstones, encountered in the western portion of the formation as distinct lenses and as a stratum underlying this formation (the Vereyan stratum). There are numerous red, pink and green marls as well as dolomites; the dolomites are of a different type, some of which occur at the western margin of the formation, adjacent to the sandstones, and the others are found within the series itself, independently of the clastic rocks. Farther on, some places contain inclusions of gypsum; in the magnesian marls there is mountain cork and occasional ratoffkite (a form of fluorite).

Like the limestones and dolomites forming the principal rocks mass of the formation, the inclusions of gypsum and perhaps of ratoffkite should also be considered parent members of the formation. The red and mottled sandstones and clays occurring in relatively thin layers or isolated lenses are allophilic members, but represent an extremely typical element of the formation.

Other relationships are characteristic of the lower part of the Viséan stage. There, too, among the limestones and occasional dolomites one encounters red, white, pale yellow and mottled clay formations, which do not, however, resemble the upper formations. These consist chiefly of that stratum which, above the Dinantian, was described by M. S. Shvetsov [26] as the Vysokov series. It consists of viscous white clays, structureless with colored streaks, containing fragments of limestones and chalcedony. This eluvial stratum is the weathered crust of the Serpukhov and older rocks. A characteristic of the Vysokov formation is the presence of kaolin and an increased amount of alumina, particularly free alumina. To the east, in the vicinity of Mikhaylovo, , these red clays (Al_2O_3 up to 25%), like "terra rossa," fill sinkholes in the limestones.

In the lowest parts of this formation, among the limestones (in places dark gray) there are coal seams, frequent interbeds of quartz sands and gray (sometimes dark gray) clays, usually carbonate, sometimes (for example, along the Zarochinka River flowing into the Serëna River above the village of Burnashovo) with abundant, excellently preserved, thin-shelled gastropods and brachiopods. Toward the northwest (at Tikhvin) the clays are richer in aluminas, as also in the underlying productive stratum, which contains a known bauxite deposit.

Thus the Viséan series (the lower part of N. M. Strakhov's formation) is an independent formation whose parent members are the limestones, dolomites and perhaps the carbonaceous interbeds, whereas the allophilic members are dark gray clays, quartz (often light colored) sands, the variegated and white kaolinic clays containing ferruginous agglomerations, and the clays enriched with alumina, perhaps bauxite.

As we shall see, the parageneses of the Middle and Upper Carboniferous strata on the one hand and the Viséan on theother are so different that they should be distinguished as two independent formations. It should also be noted that the limestones and dolomites, which are the principal members of the parent rocks, are not the same in both formations: in the lower, Viséan, formation there are many grayish limestones containing carbonaceous plant remains [26], whereas there are no such limestones in the upper formation.

The carbonate rocks of these formations also seem to show other differences: at the Moscow Institute of Geological Exploration M. S. Shvetsov has gathered many specimens of formations, particularly the carbonate platform formations described above; looking at this collection of rocks in sequence, it is easy to see the great difference between the limestones and dolomites of these associations.

Hence there is also a difference in the conditions under which the rocks of both formations were deposited: the lower formation, as M. S. Shvetsov has shown, originated in a humid tropical region; the lower formation, according to papers by I. V. Khvorova, was deposited in a basin next to a vast arid zone. Consequently these two formations are so different that they cannot be treated as one.

In addition to the two formations above, there are no doubt other platform formations of this class. One is of considerable interest: I distinguished it [20] a glauconitic-carbonate formation whose type is the Ordovician limestones of the Baltic region, whose paragenesis contains, in addition to limestones and dolomites, the following parent members: glauconitic rocks and a lenticular layer (i. e., oolitic ferruginous ores) described by I. Bok in the middle of the last century. This paragenesis is quite different and has nothing in common with the first two; hence, of course, its origin and the conditions of its formation are also quite different. The third of the formations distinguished is of interest in that its full Mesozoic-Cenozoic homologue is a Cretaceous formation. Its paragenesis is almost the same: chalk, chalky marls, glauconitic sands and sandstones, occasional phosphorites and a few oolitic ferruginous formations.

These examples were intended to show that only by studying rock parageneses can one readily and correctly identify natural associations of rocks and determine their origin. This methods also introduces much that is new into the study of sedimentary rocks themselves, since by investigating them in natural associations one will detect new characteristic features and properties. By studying the parageneses one can answer questions of the laws governing the simultaneous occurrence of rocks and the origin of the deposits composing them. Thus the word paragenesis refers not only to the determination of formations, but also to the method of studying them.

The history of distinguishing carbonate platform formations now fully confirms the correctness of the conclusions. This history is extremely simple. As pointed out at the beginning of this article, it is well known that in 1951 N. M. Strakhov expressed his views of formations in the following definition: "Carbonate rocks of the geologic past often occur as large, compact bodies formed in all their features under similar and homogeneous facies conditions of sedimentation. Such large aggregates of rock," writes M. M. Strakhov, "will henceforth be designated as formations and the conditions of their origin will be called historical-geological landscapes." Thus N. M. Strakhov's formations are distinguished according to two features: size ("large") and conditions of creation (within definite "historical-geological landscapes"). On the basis

of these concepts he distinguished, first, the abovementioned single limestone-dolomite platform formation and a Cretaceous formation which is "as it were, a supplement to the usual carbonate formations of platforms, an addition expanding the facies profile of the ancient marine carbonate formation and creating in the semipelagic portion in deeper water." Such were his concepts in 1951.

In 1956 N. M. Strakhov gave a new definition of a formation [15]: "Each paragenetic complex of sedimentary rocks developed over a fairly large areas of the earth's crust and obliged by its origin to undergo a prolonged local development of some modification of any type of sedimentary process is a formation of sedimentary rocks." Thus to his original definition (size and uniformity of conditions of formation) he added the paragenesis of the rocks comprising the formation.

Instead of analyzing all of N. M. Strakhov's highly debatable views concerning formations, I shall stress that the 1956 definition differs from that of 1951 only in its recognition of the paragenetic relationships between the members of formations. This recognition of the parageneses immediately led N. M. Strakhov to completely different and more accurate conclusions regarding the carbonate platform formations, conclusions not differing substantially from my early generalizations [20]. For example, in1956 he distinguishes a limestone-dolomite arid platform formation (C_2 and C_3 of the Russian platform!), cites a fairly correct paragenesis of the sedimentary rocks of this formation, a humid carbonaceous formation (the Ordovician of the Baltic region!!), and a Cretaceous formation with a paragenesis which indicates glauconitic sands and phosphorites (!!). Of greater interest, however, is the following remark by Strakhov: "With the relatively deep-water Cretaceous humid formation (Cr_2 of the Russian platform — N. Sh.) the limestone-dolomite arid formation (C_2-C_3 of the Russian platform — N. Sh.) generally has very few points of contact". Yet in 1951 he considered the second of these to be merely "an addition to the general carbonate formations of platforms."

This history thus testifies to the merit of the method of parageneses and to the correctness of distinguishing formations by this method.

In this paper I have attempted to set forth the essence of the parageneses of the sedimentary and volcanic rocks comprising formations. I am well aware that this is only the beginning of an investigation in this area, but it appears to me that the study of sedimentary-volcanogenic parageneses will proceed in precisely this direction in discovering the genetic relationships between rocks.

We have touched on only a few aspects of this great problem, the simplest perhaps and the most important. Nevertheless it seems that work in this direction will rapidly expand the area of investigation and will introduce new concepts and generalizations to science.

Although the types of paragenetic relationship between rocks and the classification of the members comprising formations have been considered separately in this article, between the paragenetic relationships of the rocks and the laws governing their successive location within formations there is probably relationship which is sometimes quite clearly expressed. By the example of the division of formations into symmetrical and asymmetrical (corresponding to autochthonous and allochthonous), we have shown the influence exerted by the nature of the directivity of the sedimentation process on the general characteristics of the association of rocks. I am of the opinion that in the future it will be possible to distinguish other types of paragenetic relationships in this manner.

There also arises the question of the number of rock associations in formations (that is, the problem of the paragenesis of rock associations) I have in mind here not the paragenesis of formations occurring in series of formations which are regularly repeated in the earth's crust, but the paragenesis of rock associations within formations.

In the description of the types of members of parageneses it was mentioned that among the rocks of formations (probably not in all, but in many or most cases) it is possible to distinguish not one but two or more parageneses, and not one but several paragenetic groups, as, it seems, these parageneses within formations should be termed. The kinds of relationships between these groups, the manner in which they form combinations and these combinations chang in time and in geological space — these are all questions of great importance in the study of formations. There is no doubt of the existence of parageneses of facies series within formations, but the series and the groups in which they are combined in nature are little known, for we know little of these series themselves.

REFERENCES

1. Arkhangel'skiy, A. D., Vvedeniye v izucheniye geologii Yevropeyskoy Rossii. [INTRODUCTION TO STUDY OF THE GEOLOGY OF EUROPEAN RUSSIA]: Ch. 1, Gosizdat, 1923.

2. Arkhangel'skiy, A. D., Geologicheskoye stroyeniye SSSR. [GEOLOGIC STRUCTURE OF THE USSR]: Ch. 1, Gos. nauchn. -tekhn. geol. -razved. izd-vo, 1932.

3. Arkhangel'skiy, A.D., and N.S. Shatskiy, Skhema tektoniki SSSR. [TECTONICS OF THE USSR]: Byul. Mosk. o-va ispyt. prirody, otd. geol. t. 11, no. 4, 1933.

4. Arkhangel'skiy, A.D., N.S. Shatskiy, et al., Kratkiy ocherk geologicheskoy struktury i geologicheskoy istorii SSSR. [BRIEF OUTLINE OF THE GEOLOGIC STRUCTURE AND GEOLOGIC HISTORY OF THE USSR]: Izd-vo Akad. Nauk SSSR, 1937.

5. Bok, I., Geognosticheskoye opisaniye nizhnesiluriyskoy i devonskoy sistemy S.-Peterburgskoy gub. [GEOGNOSTIC DESCRIPTION OF THE LOWER SILURIAN A AND DEVONIAN SYSTEMS OF THE SAINT PETERSBURG GUBERNIYA]: In the book Materialy dlya geol. Rossii. [MATERIALS FOR A GEOLOGY OF RUSSIA]: T. 1, 1869.

6. Bushinskiy, G.I., Petrografiya i nekotoryye voprosy genezisa yegor'yevskikh fosforitov Mosk. obl. [PETROGRAPHY AND SOME PROBLEMS OF THE GENESIS OF THE YEGOR'YEV PHOSPHORITES OF THE MOSCOW OBLAST]: Byul. Mosk. o-va ispyt. prirody, otdel geol., t. 15, no. 5, 1937.

7. Davydova, T.N. and Ts.L. Gol'dshteyn, Litologicheskiye issledovaniya v Bureinskom basseyne. [LITHOLOGICAL INVESTIGATIONS IN THE BUREIN BASIN]: Gosgeolizdat, 1949.

8. Il'ina, N.S., L.M. Yelina, et al, Kamennougol'nyye oltozheniya tsentral'nykh oblastey Russkoy platformy. [CARBONIFEROUS DEPOSITS OF THE CENTRAL REGIONS OF THE RUSSIAN PLATFORM]: Gostoptekhizdat, 1958.

9. Kazakov, A.V., Litologiya i protsessy vyvetrivaniya fosfatnoy kolonki tsentral'nykh yegor'yevskoy grupy mestorozhdeniy. [LITHOLOGY AND PROCESSES OF WEATHERING OF THE PHOSPHATE CORE OF THE YEGOR'YEV GROUP OF DEPOSITS: In the book, Fosfority Mosk. obl. [PHOSPHORITES OF THE MOSCOW REGION]: Tr. nauchn. in-ta po udobreniyam i insektofungisidam no. 140, 1938.

10. Kay, M., Geosinklinali Severnoy Ameriki. [NORTH AMERICAN GEOSYNCLINES]: Izd-vo in. lit., 1955.

11. Miropol'skiy, L.M., L.F. Solontsov and N.M. Kovyazin, Ob oolitovykh rudakh v nizhnefranskikh otlozheniyakh Bashkiri i Tatarii. [CONCERNING THE OOLITIC ORES IN THE LOWER FRASNIAN DEPOSITS OF BASHKIRIYA AND TATARIYA]: Izv. Kazan. fil. Akad. Nauk SSSR, ser. geol., no. 1, 1950.

12. Nalivkin, D.V., Ucheniye o fatsiyakh. Geograficheskiye usloviya obrazovaniya osadkov. [THEORY OF FACIES. GEOGRAPHIC CONDITIONS OF THE FORMATION OF DEPOSITS]: T. 1-2, Izd-vo Akad. Nauk SSSR, 1955-1956.

13. Osipova, A.I., Usloviya obrazovaniya dolomitov v Ferganskom zalive paleogenovogo morya. [CONDITIONS OF FORMATION OF THE DOLOMITES IN THE FERGANA BAY OF THE PALEOGENE SEA]: In the book, Tipy dolomitovykh porod i ikh genezis. [TYPES OF DOLOMITIC ROCKS AND THEIR GENESIS]: Tr. Geol. in-ta, no. 4, 1956.

14. Strakhov, N.M., Izvestkovo-dolomitovyye fatsii sovremennykh i drevnykh vodoyemov. [CALCAREOUS-DOLOMITIC FACIES OF MODERN AND ANCIENT BASINS]: Tr. In-ta geol. nauk Akad. Nauk SSSR, no. 124 (geol. ser., no. 15), 1951.

15. Strakhov, N.M., Tipy osadochnogo protsessa i formatsii osadochnykh porod. [TYPES OF SEDIMENTARY PROCESS AND FORMATION OF SEDIMENTARY ROCKS]: Articles 1 and 2, Izv. Akad. Nauk SSSR, ser. geol., no. 5 and 8, 1956.

16. Tikhiy, V.N. et al., Devonskiye otlozheniya. Volgo-Ural'skaya neftenosnaya oblast'. [DEVONIAN DEPOSITS. THE VOLGA-URALS OIL REGION]: Tr. vses. n.-i. geol.-razv. in-ta, no. 106, 1957.

17. Forsh, N.N., Permskiye otlozheniya. Ufimskaya svita i Kazanskiy yarus. [PERMIAN DEPOSITS. THE UFA SUITE AND THE KAZANIAN STAGE]: Tr. Vses. neft. n.-i. geol.-razv. in-ta, nov. ser., no. 92, 1955.

18. Khvorova, I.V., Istoriya razvitiya sredne- i verkhnekamennougol'nogo morya zapadnoy chasti Moskovskoy sineklizy. [HISTORY OF THE MIDDLE AND UPPER CARBONIFEROUS SEA IN THE WESTERN PART OF THE MOSCOW SYNECLISE]: Tr. Paleontol. in-ta Akad. Nauk SSSR, vol. 43, 1953.

19. Shatskiy, N.S., (O razvitii zemnoy kory.) Tezisy doklada. V st. Na teoreticheskom fronte sovetskoy geologii. [(ON THE DEVELOPMENT OF THE EARTH'S CRUST.) ABSTRACT OF REPORT. IN THE ARTICLE ON THE THEORETICAL FRONT OF SOVIET GEOLOGY]: Sov. geologiya, vol. 9, no. 8, 1939.

20. Shatskiy, N.S., Fosforitonshyye formatsii klassifikatsiya fosforitovykh zalezhey. V kn. Soveshchaniye po osadochnym porodam. [PHOSPHORITE-BEARING FORMATIONS AND THE CLASSIFICATION OF PHOSPHORITE DEPOSITS]: In the book, Soveshchaniye po osadochnym porodam. [CONFERENCE ON SEDIMENTARY ROCKS]: No. 2, Izd-vo Akad. Nauk SSSR, 1955.

21. Shatskiy, N.S. and V.V. Veber, Miotsev yugo-vostochnogo okonchaniya Kavkaza. [THE MIOCENE OF THE SOUTHEASTERN END OF THE CAUCASUS]: Byul. Mosk. obshch. ispyt. prirody, otd. geol., t. 9, no. 3-4, 1931.

22. Shatskiy, N.S., O margantsenoshykh formatsiyakh i o metallogenii margantsa. [MANGANIFEROUS FORMATIONS AND THE METALLOGENY OF MANGANESE]: Izv. Akad. Nauk SSSR, ser. geol., no. 4, 1954.

23. Shatskiy, N.S., O fosforitonosnom kul'me Karagandinskogo basseyna. [THE PHOSPHORITE-BEARING CULM OF THE KARAGANDA BASIN]: Izv. Akad. Nauk SSSR, ser. geol., no. 3, 1955.

24. Shatskiy, N.S., Yu.A. Kosygin, A.V. Pyeve, Yu.M. Pushcharovskiy, N.P. Kheraskov, N.A. Shtreys and A.L. Yanshin, K voprosy o periodichnosti osadkoobrazouraniya i o metode aktualizma v geologii. [THE PROBLEM OF THE PERIODICITY OF SEDIMENTATION AND THE METHOD OF ACTUALISM IN GEOLOGY]: In the collection, K voprosu o sostoyanii nauki ob osadochnykh porodakh. [THE STATE OF THE SCIENCES OF SEDIMENTARY ROCKS]: Izd-vo Akad. Nauk SSSR, 1951.

25. Shatskiy, S.B., Zhelezonoshyye verkhnemelovyye otlozheniya vostochnoy chasti Zapadno-Sibirskoy nizmennostii. [THE FERRUGINOUS UPPER CRETACEOUS DEPOSITS OF THE EASTERN PART OF THE SIBERIAN LOWLAND]: Vestn. Zap.-Sib. geol. upr., no. 1, 1957.

26. Shvetsov, M.S., Istoriya Moskovskogo kamennougol'nogo basseyna v dinantskuyu epokhu. [HISTORY OF THE MOSCOW COAL BASIN IN THE DINANTIAN EPOCH]: Tr. Mosk. geol.-razv. in-ta, vol. 12, 1938.

27. Shvetsov, M.S., Petrografiya osadochnykh porod. [PETROGRAPHY OF SEDIMENTARY ROCKS]: Gosgeoltekhizdat, 1958.

28. Yakhimovich, V.L., and O.S. Adrianova, Kaynozoy Bashkirskogo Predural'ya. [THE CENOZOIC OF THE BASHKIR-URALS REGION]: T. 1, ch. 1 and 3. Ufa, 1958-1959.

29. Bramlette, M.N., The Monterey formation of California and the Origin of its siliceous rocks. U.S. Geol. Surv., Prof. paper 212, Washington, 1946.

30. Calom, G., Les moronites du détroit Nord-Bétique (Espagne). Congrès geol. Internat. Comptes rendus de la XIX Session, Algérie 1952, sectiona XIII, Fasc. XIII, Alger, 1954.

31. Gottis, C. and P. Sainfeld, Les gîtes méttalifères tunisiens. XIX Congrès géol. Internat. Monographies régionales. 2me ser. Tunisie, no. 2, 1952.

32. Kennedy, W.Q., Sedimentary differentiation as a Factor in the Moine-Torridonian correlation. Geol. Magaz., vol. 88, no. 1, 1951.

33. De Launay, L., Traité de métallogénie. Gîtes mineraux et métallifères. Vol I et II. Paris, 1913.

34. Niggli, P., Gesteine und Minerallagerstätten. Bd. II. Exogene Gesteine und Minerallager stätten. Basel, 1952.

35. Pettijohn F.J., Sedimentary Rocks, 2nd ed., New York, 1949.

36. Solignac, M., Les caractères minéralogiques du minéral de fer oolitique du Dj. Anoc (Tunisie méridionale). C.R. Acad. Sci., Paris, 1936.

Geological Institute,
Academy of Sciences U.S.S.R.
Moscow

Received February 22, 1960

PALEOZOIC DEPOSITS OF THE OMULEV MOUNTAINS[1]

by

N. A. BOGDANOV AND M. N. CHUGAYEVA

The Omulev Mountains form the southeastern portion of the Cherskiy mountain ranges. They extend in northwestward for a distance of 150 - 200 km, with a width of 50 km. Structurally they include rocks of the Lower and Middle Paleozoic, comprising the southwestern part of the Cherskiy uplift — the marginal uplift of the Central Kolyma massif [9]. The Paleozoic rocks within the Cherskiy uplift are compressed into simple gently sloping folds with a northwestward strike and complicated by small folds in zones of discontinuous dislocations. As a rule, the latter are located on the flanks of the folds, emphasizing the general block-folded structure of the uplift.

The first geological investigations in the region of the Omulev Mountains were made in the middle thirties by S. V. Novikov and P. I. Skornyakov [4], and also by Yu. N. Trushkov [11], who studied the geological structure of the southern and western portions of the Omulev Mountains in the Taskan and Omulevka River basins. Among the Paleozoic formations they distinguished Cambrian, Ordovician, Silurian, Devonian and Lower Carboniferous deposits. Nevertheless subsequent work did not confirm the presence of Cambrian deposits within this region. More thorough and detailed studies in the Omulev Mountains were made by A. A. Nikolayev [3]. He worked out the stratigraphy of the Lower and Middle Paleozoic deposits and distinguished the tectonic structures. In addition to the work cited, general questions of the tectonic structure of the Cherskiy uplift and its structural position have been discussed in papers by S. V. Obruchev [6], P. N. Kropotkin and Ye. T. Shatalov [2], Yu. M. Pushcharovskiy [7, 8] and L. A. and B. A. Snyatkov [10].

In 1957 and 1958 the authors of the present article made some geologic investigations in the northwestern portion of the Omulev Mountains, along the Omulevka River and its tributaries. We gathered a rich paleontological collection of specimens, of which the graptolites were identified by A. M. Obut, the tabulates by Yu. I. Tesakov and V. I. Dubatolov, the gastropods by V. A. Vostokova, the nautoloids by Z. G. Balashov, the Devonian brachiopods by M. A. Rzhonsnitskaya, the bryozoa by Ye. A. Modzalevskaya, the Carboniferous brachiopods by V. N. Krestovnikov and the foraminifera by Ye. A. Reytlinger, to whom we wish to express our sincere gratitude. The data permit refinement of the Paleozoic stratigraphic scheme of this region prepared by A. A. Nikolayev (Figure 1) and a more detailed reconstruction of the Paleozoic history of the southern part of the Kolyma central massif.

STRATIGRAPHY

Within the Omulev mountains (Figure 2) there is an extensive development of Lower and Middle Paleozoic deposits, which lie, with conglomerates at their base, upon Precambrian metamorphic rocks.

PRECAMBRIAN

The Precambrian rocks in the Omulev Mountains are not extensive, but occur as outcrops along the right tributaries of the Uochat River, in the crest of the Uochat horst-anticline, as well as along the Dvoynaya and Zhuravl' creeks within the small Zhur horst. The Precambrian rocks are usually crumpled into symmetrical folds, sometimes complicated by smaller folds and plications. The most complete section through the Precambrian deposits is found along the Dvoynaya and Zhuravl' creeks, where two strata can be distinguished by their composition and degree of metamorphism. The lower stratum consists of gray and silvery-gray biotite-quartz schists with infrequent intercalations of gray, almost white quartzites; the visible thickness is 300-350 m. The upper stratum consists of zoisite-quartz, quartz-epidote and sericite-quartz schists with interlayers of white marble limestones; the thickness is 700-800 m. The total thickness of the metamorphic rocks in the Dvoynoy valley is 1000-1100 m.

[1]Paleozoyskiye otlozheniya Omulevskikh gor.

After A.A. Nikolayev (1957) | After N.A. Bogdanov and M.N. Chugayeva (195

Group	System	Series	Stage	Suite	Sub-suite	Suite	Stage	Series	System	Group
Paleozoic	Carboniferous	Lower						Lower	Carboniferous	Paleozoic
	Devonian	Upper	Famennian			Serdar	Famennian	Upper	Devonian	
			Frasnian			Salazh	Frasnian			
		Middle	Givetian			Voyakh	Givetian	Middle		
			Eifelian	Urul'tun		Urul'tun	Eifelian			
						Pelosska				
		Lower		Vechera		Vechera		Lower		
				Nelyudim		Nelyudim				
	Silurian	Upper	Upper Ludlovian				Ludlovian	Upper	Silurian	
			Lower Ludlovian			Bizon				
		Lower	Wenlockian			Omulev	Llandoverian, Wenlockian	Lower		
			Llandoverian	Omulev	Upper					
					Middle	Omuk	Upper Caradocian, Ashgillian	Upper	Ordovician	
					Lower	Kharkindzha	Lower Caradocian	Middle		
				Darpir		Darpir	Llandeilian			
				Krivun		Krivun				
	Ordovician	Upper		Mokra		Mokra				
				Siyen		Siyen				
		Middle		Uochat						
				Zhuir		Zhuir	Llanvirnian			
Proterozoic										Proterozoic

FIGURE 1. Comparison of the stratigraphic schemes for the Paleozoic deposits of the Omulev mountains

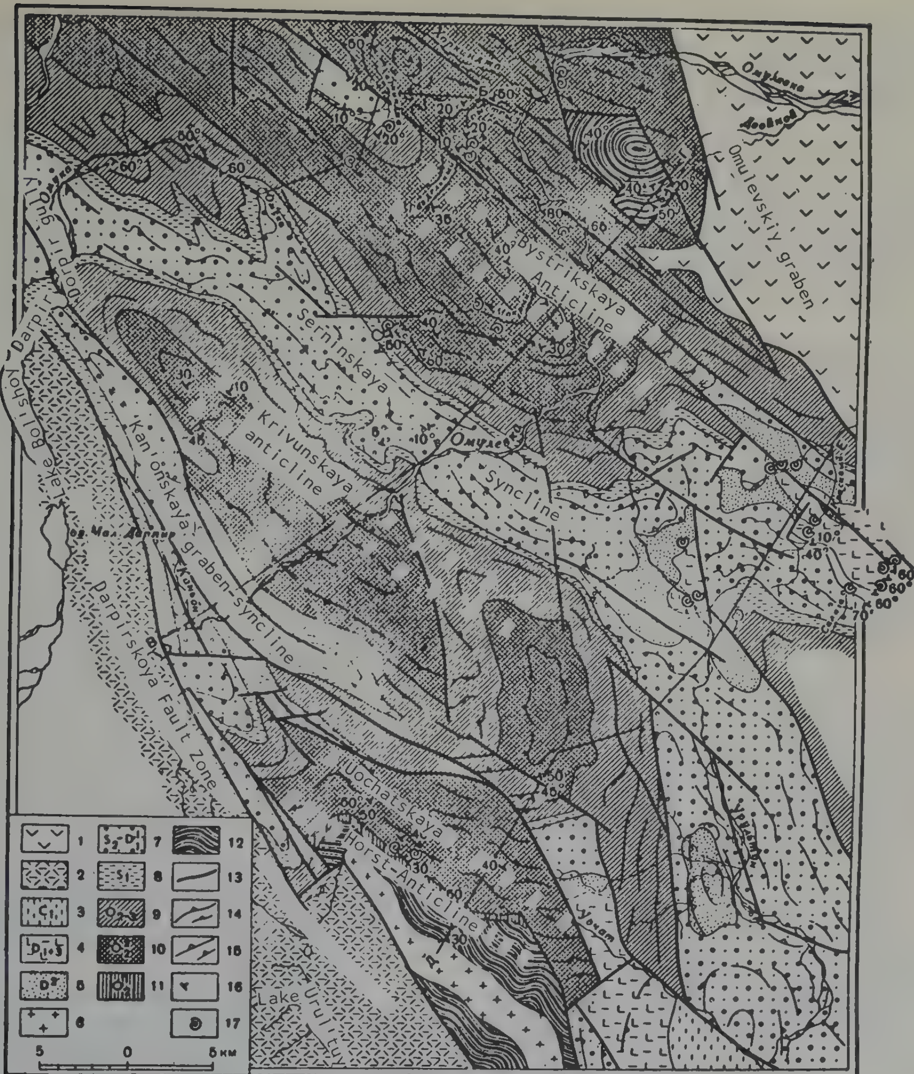

FIGURE 2. Structural-geologic sketch map of the Omulev mountains:

1 - Upper Jurassic; 2 - Upper Triassic — Middle Jurassic; 3 - Lower Carboniferous; 4 - Middle and Upper Devonian; 5 - Lower Devonian; 6 - granites (Pz); 7 - Upper Silurian — Lower Devonian; 8 - Lower Silurian; 9 - Middle and Upper Ordovician (Darpir, Kharkindzha and Omuk suites); 10 - Middle Ordovician (Siyen, Mokra and Krivun suites); 11 - Middle Ordovician (Zhuir suite); 12 - Precambrian; 13 - faults; 14 - Ordovician strikes; 15 - Silurian and Devonian strikes; 16 - structural symbols; 17 - faunal occurrences.

The profile of the Precambrian formations along the right tributaries of the Uochat River is somewhat different. Here at the base there lies a stratum of biotite-quartz and biotite-quartz-chlorite schists with interlayers of white micaceous marbles, the total thickness of which is approximately 500 m. Higher in the section they are gradually replaced by gray and steel-gray muscovite-quartz schists with interlayers and lenses of limestone altered to marble and quartzites; the total thickness is approximately 600 m. In the central portion of the Uochat horst-anticline the stratum of biotite-quartz schists is cut through by a large granitic intrusion of Paleozoic age, and is broken by the disjunctive dislocations of the Darpir fault zone. At the contact with the granites, the schists are intensively altered to hornfels and migmatized. In the fault zone the biotite-quartz schists are transformed into

cataclasites and mylonites with characteristic gneissic and banded textures. The visible total thickness of the metamorphic schists in the Uochat River basin is 1000-1100 m.

On the whole, the section through the metamorphic rocks exposed along the right tributaries of the Uochat River differs from the Precambrian section along the Dvoynoy and Zhuravl' creeks in containing of numerous thin interlayers of marbleized limestones, and in the lesser degree of metamorphism of the upper part of the section.

The age of the metamorphic formations along the Zhuravl' and Dvoynoy creeks, as well as along the right tributaries of the Uochat River, is still not precisely established. In the Uochat River valley the metamorphic schists are covered by deposits of the Middle Ordovician Zhuir suite, with conglomerates at its base. On the basis of the degree of metamorphism of the rocks and their composition, the stratum of metamorphic schists exposed along the Uochat River and the Dvoynoy and Zhuavl' creeks will tentatively be called Late Precambrian.

PALEOZOIC

The Paleozoic formations of the Omulev Mountains are chiefly carbonate rocks and are well characterized paleontologically, so that among them one can distinguish formations of the Ordovician, Silurian, Devonian and Lower Carboniferous ages (Figure 3).

The Ordovician deposits form the flanks and central parts of the anticlinal structures. The rocks of the Middle Ordovician are more extensive in occurrence and whereas Upper Ordovician are less widespread. No deposits of the Lower Ordovician are exposed in the Omulev Mountains.

The Middle Ordovician is exposed in the Illanvirnian, Llandeilian and Lower Caradocian stages. The base of the Middle Ordovician section consists of the Zhuir suite, which is best represented on the northern flank of the Uochat horst-anticline. Here, without any visible angular unconformity, upon limestones altered to marble and metamorphic schists with a 40-meter packet of conglomerates at the base, there lie dark-gray calcareous-argillaceous phyllitized slates with interbeds of granular limestones. The total thickness of the suite is 140-150 m.

In the lower reaches of the left tributaries of the Omulevka River, at Bystry creek and the Kharkindzha River, in Zhuir suite contains green-gray and dark gray calcareous-argillaceous shales and marls with interbeds of nodular limestones. Along the lower reaches of the Kharkindzha River these deposits have been found to contain Didymograptus ex gr. bifidus (Hall) and Tetragraptus sp., which are common in the Llanvirnian stage of the Middle Ordovician.

Limestones of the Siyen suite lie above the Zhuir suite. A direct contact between the two suites is observed along the Zhuir River, where the Siyen suite lies conformably on the underlying stratum and gray thick-bedded clastic limestones begin to appear. Middle Ordovician gastropods and bryozoa in the lower 10 m. The overlying formation, belonging to the Siyen suite, is devoid of fossils in this section. The total thickness of the suite in the northern flank of the Uochat horst-anticline is 1000 m.

To the northwest, on the left bank of the Omulevka River, the Siyen suite consists, from bottom to top, of the following:

1. Massive, jointed gray limestones; 150-180 m.

2. Dark gray argillaceous limestones with Pliomerops sp., I, Calliops cf. armatus Ulr. et Delo, Eorobergia sp., Asaphidae, Egorella campacta V. Ivan, Tetradella sp., Laccoprimitia sp., as well as brachiopods and gastropods; 214 m.

3. Dark gray thick-bedded limestones with Eorobergia sp., Pliomerops sp. I, Pl. sp. II, Amphilichas sp., Lonchodomas sp., Cybele sp. indet., Ceraurinus sp., Illaenus sp. and Asaphidae. In addition to the trilobites, there are numerous ostracoda, brachiopods and gastropods (among the latter are Loxonema sp., Pararaphistoma sp.); 195 m.

4. Massive light-gray granular limestones with Isotelus cf. maximus Locke, Illaenus cf. latiaxiatus Raym., Ill. aff. marginalis Raym., Ceraurus sp., Primitia sp., Trilobella sp. and brachiopods. Thickness 400 m.

The total thickness of the suite here is approximately 1000 m.

Higher in the section the limestones of the Siyen suite are conformably overlain by the rocks of the Mokry suite, represented by bluish-gray marls and dark gray argillaceous limestones. The lower part characteristically contains nodular argillaceous limestones. Paleontologically the Mokry suite is quite indeterminate: it contains only sparse brachiopods of the genus Raphinesquina. The total thickness of the suite is 500 m.

The shales of the Krivun suite overlie the rocks of the Mokry suite and connect with them in a gradual transition. More complete sections through the Krivun suite are exposed along the Krivun and Mokry creeks; here these sections are composed of dark gray, sometimes almost

black, argillaceous and calcareous-argillaceous shales with thin interbeds of limestones. Only occasionally do these interbeds reach a thickness of 30-40 m; as a rule they do not exceed 0.5 m. In the lower half of the Krivun suite, along Mokry creek, specimens of Climacograptus sp. and Glyptograptus aff. euglyphus Lapw., characteristic of the Llandeilian stage of the Middle Ordovician, have been collected. The total thickness of the Krivun suite is 700-750 m.

The Darpir suite conformably overlies the Krivun suite with a gradual transition. In the sections along the Krivun and Omuka creeks and the Kharkindzha River these suites consist of massive pelitomorphic and argillaceous limestones. They are characterized by an almost complete absence of clay shales. In the middle portion of the Darpir suite, along Krivun creek, trilobites were collected: Cybele aff. planifrons Web., Stygina sp., Ampyx sp., Spaerexachus sp., Trinucleus sp., Ceraurinus sp. and Harpes sp., as well as isolated brachiopods and ostracoda. The thickness is approximately 700-800 m.

The Middle Ordovician section ends with the deposits of the Kharkindzha suite, conformably overlying those below and consisting chiefly of black argillaceous and calcareous-argillaceous shales with calcareous concretions. More typical sections are observed along the Kharkindzha River and the Omuka and Mokry creeks. The lower part of the suite along the Kharkindzha River contains the graptolites Dicranograptus aff. celticus Elles et Wood and Diplograptus multidens Elles at Wood (upper zone of the Llandeilian stage — the D. multidens zone). In the upper half of the suite Climacograptus sp., Orthoglaptus ex gr. calcaratus (Lapw.), Glyptograptus sp., Dicranograptus ex gr. romosus (Hall.), Dicellograptus sp. (upper zone of the Caradocian stage) were collected. Finally, 5 m from the top of the suite there are numerous graptolites of the genera Rectograptus sp. and R. ex gr. truncatus (Lapw.). The last form is also common in the younger deposits and is encountered in the lower portions of the Upper Ordovician.

The presence of the abovementioned graptolites suggests that the Kharkindzha suite corresponds in age to the upper parts of the Llandeilian and Lower Caradocian stages. For a precise determination of the upper age boundary of the suite, additional specimens of fauna must be collected.

Much less extensive is the Upper Ordovician, of which the Upper Caradocian and Ashgillian stages have been found. The deposits of this include the Omuka suite, which here lies conformably on the Kharkindzha and connects with the latter in a gradual transition. The composition of the suite includes cross bedded calcareous siltstones and sandstones interbedded with silty limestones and calcareous-argillaceous shales with a thickness of 200 m. In these were found specimens of Diplograptus sp. The stratigraphic position of the suite suggests that its age is Upper Ordovician.

In concluding this description of the Ordovician, it should be pointed out that the region of the Omulev Mountains is one of the most interesting for the study of the deposits of this age. Here there is an alternation of formations consisting chiefly of limestones with formations in which shales predominate.

In the former the deposits contain brachipods, gastropods, trilobites, ostracoda and other groups of fossil organisms. In addition, among the ostracoda and trilobites there are a number of forms close to those which are encountered in the Ordovician of the Siberian platform, so that a study of these groups may permit correlation of the Ordovician deposits of the northeastern U. S. S. R. with those of the Siberian platform. On the other hand, in the shale suites considerable numbers of graptolites are encountered, which permits precise determination of their age.

The Silurian deposits are developed over the same area as the Upper Ordovician, and are connected with the latter by gradual transitions. They form the flanks and central portions of the synclinal structures. The lower boundary of the Silurian deposits is tentatively traced along the sandstones and arenaceous limestones of the Omuka suite.

The Lower Silurian deposits are distinguished in a single Omulev suite which extends over a considerable area and has been described in the bottomlands of the Mokry and Bizon creeks and in the Kharkindzha River valley. This suite consists of clay shales, marls, argillaceous limestones and more rarely calcareous conglomerates.

In the section along the Mokry creek, and above the arenaceous limestones of the Omuka suite, after a small discontinuity in the outcrops, there are:

1. Solid gray arenaceous limestones alternating with calcareous-argillaceous shales containing Petalolithus palmeus (Barr.), Pernerograptus ex gr. revolutus Kurch., Climacograptus sp. indet., Monograptus sp., Diversograptus sp. (upper portion of the Lower-Middle Llandoverian); 10 m.

2. Black calcareous-argillaceous shales and argillaceous limestones with lens-shaped inclusions of calcareous conglomerates; 30 m.

3. Black platy clay shales with interbeds of gary limestones. The shales contain graptolites: Retiolites sp., Monograptus halli

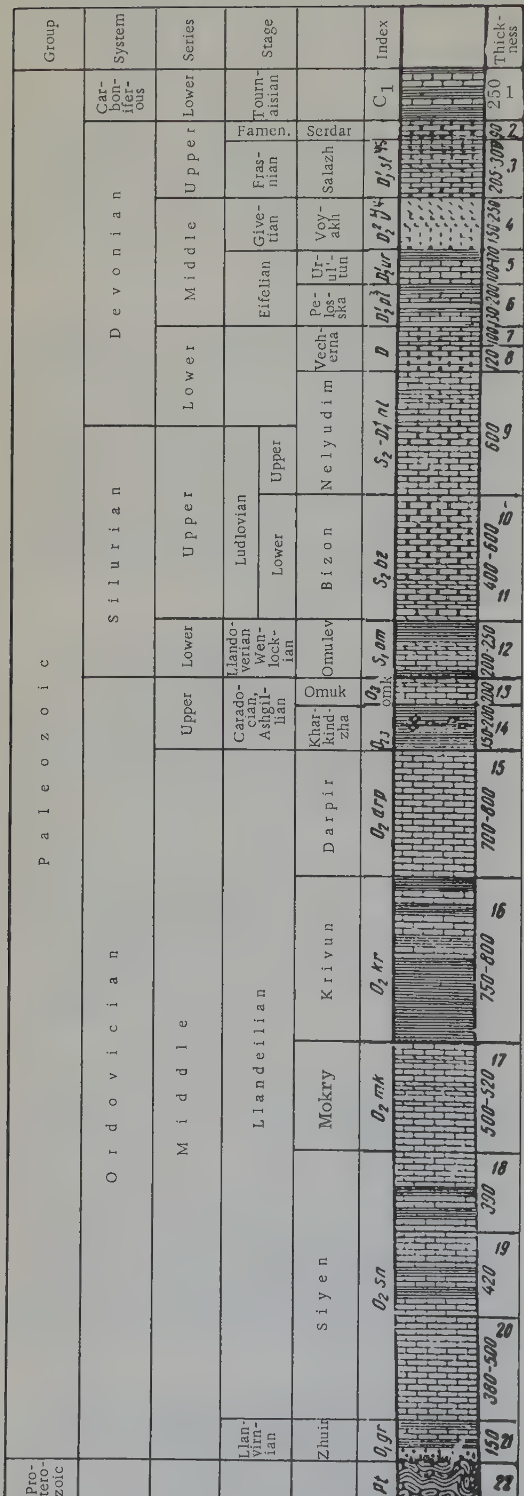

FIGURE 3. Composite stratigraphic profile through the deposits of the Lower and Middle Paleozoic of the Omulev mountains.

Lithologic characteristics	Paleontological characteristics
1. Black shales with limestone interbeds	Dictyoclostus ex gr. semireticulatus Mart., Linoproductus ex gr. cora D'Orb., Hyperimina moderata Malakh., H. vulgaris var. minor Raus.
2. Thick-bedded dark gray dolomites	Cyrtospirifer cf. whiteney Hall, Productella ex gr. speciosa Hall
3. Gray and brownish gray thick-bedded limestones with marl interbeds	Mucrospirifer novosibiricus Toll., Atrypa tubaecostata Daeck., A. tenusisulcata Wen. A. ex gr. reticularis L., A. ex gr. aspera Schloth., Gypidula ex gr. comis Owen, Mucrospirifer (?) sp., Crytospirifer sp., Atrypa sp., Elytha sp., Gypidula sp., Productella sp., Emaneulla takwanensis Kayser., Schizophoria aff. striatula Schloth.
4. Red and yellow marls, light gray anhydrites, brown dolomitized limestones and brecciated dolomites	—
5. Gray limestones	Acrospirifer subgregarius omulevskiensis Rzon., A. ex gr. gerolsteinensis Stein., Gypidula acutolobata omulevskiensis Rzon., Atrypa ex gr. reticularis L., Elythyna ex gr. salairica Rzon., Elytha cf. pseudoaculeata Rzon., Stropheodonta aff. bitubirosa Grünw. Nudirostra (?) salagaensis Rzon.
6. Black calcareous-argillaceous shales with limestone interbeds	Acrospirifer? minor Rzon.
7. Gray, thick-bedded dolomitized limestones 8. Dark gray dolomites	Punctatrypa munieri Grünw. Atrypa kolymensis Nal., Spinatrypa taskanensis Nal., Gypidula optata Barr., Chonetes ex gr. sarcinulata Schloth., Eospirifer cf. irbitensis Tscher.
9. Massive dark gray dolomitized limestones with occasional marl interbeds	Carinatina ex gr. arimaspus Eichw., Delthyris cf. tiro Barr., Tham nopora elegantula Tschud., Th. javorskii Dubat. Favosites mammilatus Tscher.

Lithologic characteristics	Paleontological characteristics
10. Light gray, pink, white and yellow dolomites with occasional red marl interbeds	Conchidium vogulicum var. kolymensis Nikif., Protathyris sp.
11. —	Monograptus sp. indet
12. Alternating calcareous-argillaceous shales and marls with dark gray, thick-bedded limestones	Monograptus flemingi Salt. M. testus Barr., Spirograptus turriculatus Barr., Monograptus halli Barr., Pristiograptus ex gr. gregarius Lapw., Pr., concinnus Lapw., Pernerograptus ex gr. revolutus Kurck., Petalolithus palmeus Barr.
13. Calcareous sandstones and argillaceous limestones	Diplograptus sp.
14. Black calcareous-argillaceous shales with loaf-shaped calcareous concretions	Rectograptus ex gr. truncatus Lapw., Orthograptus ex gr. calcaratus Lapw., Dicranograptus ex gr. ramosus Hall, Dicrangoraptus aff. celticus Elles et Wood, Diplograptus multidens Elles et Wood
15. Massive gray limestones	Cybele aff. plainfrans Web., Stygina sp., Ampyx sp., Sphaerexochus sp., Trinucleus sp. Illaenus sp., Ceraurinus sp.
16. Dark gray argillaceous shales with limestone interbeds	Climacograptus sp., Glyptograptus aff. euglyphus Lapw.

Lithologic characteristics	Paleontological characteristics
17. Alternating gray and nodular limestones with dark gray marls	Raphinesquina sp.
18. Gray pelitomorphic, thick-bedded limestones with thin interbeds of calcareous-argillaceous schists	Illaenus cf. maximus Lock., Ill. cf. latiaxiatus Raym., Thaleops sp., Ceraurus sp., Primitia sp., Trilobella sp.
19. Platy, dark gray limestones with interbeds of argillaceous limestones and marls	Calliops cf. armatus Ulr et Delo, Eorobergia sp., Pliomerops sp., Ceraurinus sp., Asaphidae, Egorella compacta V. Ivan., E. defecta V. Ivan. Tetradella sp., Laccoprimitia sp.
20. Massive gray limestones	Maclurites sp.
21. Dark gray argillaceous-calcareous shales with interbeds of limestone Brown schistose conglomerates	Didymograptus ex gr. bifidus Hall, Tetragraptus sp.
22. Metamorphic schists with interlayers of marbles and quartzites	

(Barr.), M. marri Perner. M. sp., Spirograptus turriculatus (Barr.), Streptograptus exiquens (Nich.) (the lowest layers of the Wenlockian group, at the boundary with the Llandoverian Spirograptus turriculatus zone); 10 m.

4. Fine-grained platy limestones with thin argillaceous selvages; 4 m.

5. Light platy limestones with interbeds of coarse clastic limestones and calcareous conglomerates; 50-70 m.

6. Calcareous-argillaceous shales with Monograptus sp. indet.; 10-12 m.

7. Gray granular limestones with thin argillaceous selvages, containing Monograptus flemingi (Salt.) and M. testus (Barr.) (upper Wenlockian); 35 m.

The thickness of the suite here is 170-180 m.

In this section through the Omulev suite it is possible to trace a gradual transition in the graptolites from the Lower Llandoverian to the Upper Wenlockian. In this section there is almost no representation of the Middle Llandoverian assemblage of graptolites, which is most abundant in several other profiles of the Omulev mountains and has been described in detail by A. M. Obut (1959). The thickness of the Omulev suite is irregular and varies from 200 to 230 m along the Kharkindzha River and from 180 to 160 m along Bizon creek.

Lithologically the deposits of the Upper Silurian Bizon suite are quite different from the underlying rocks. In the sections along the Bizon and Krasivyy creeks and the Kharkindzha River one can observe that the calcareous shales of the Omulev suite, without any apparent discontinuity, are conformably overlain by white granular dolomites forming the base of the Bizonskaya suite. Higher in the section the white dolomites are replaced by darker-colored varieties alternating with interbeds of red and green marls. The thickness of the deposits of the Bizon suite reaches 750 m; from southwest to northeast it decreases noticeably, and reaches 250 (along the Omuka creek) and 150 m (Kharkindzha River).

Paleontologically the Bizon suite is quite indeterminate. At its base along the Krasivyy creek it has been possible to find Monograptus sp. of Ludlovian appearance. In the more eastern regions A. A. Nikolayev [3] mentions Conchidium vogulicum kolymensis for this suite Nikif. (in coll.), common in the Lower Ludlovian.

Upper Silurian — Lower Devonian. The Bizon suite is overlain by the rocks of the Nelyudim suite, which is encountered almost everywhere. Its lower boundary is traced along the top of the white dolomites of the Bizon suite.

The Nelyudim suite is characterized by the presence of massive gray and thick-bedded limestones, dolomites and dolomitized limestones, often filled with tabulates. In the middle portion of the suite there are specimens of Favosites inammilatus Tschern. et al., which are encountered in the upper strata of the Upper Ludlovian. In the uppermost part of the suite the tabulates are represented by well known Devonian forms (Thamnopora elegantula Tchud., Th. javorskyi Dubat.) and in the section along Salaga River Devonian brachiopods have been collected (Carinatiana ex gr. arimaspus Eichw., Delthyris cf. tiro Barr.). The thickness of the Nelyudim suite is inconstant and increases considerably toward the northwest: along the middle reaches of the Krasivyy creek it does not exceed 350 m, while in the upper reaches it increases to 750 m. On the basis of these data the age of the suite is thought to be Upper Silurian — Lower Devonian.

Devonian formations are widely developed in the eastern portion of the region under study, where they fill the central, more depressed portions of synclinal structures. These deposits have been discussed in detail by the present writers in another work; hence we shall give only a brief characterization here, without complete lists of the fauna. It should be pointed out that the Devonian and Lower Carboniferous deposits, as well as the underlying deposits, are connected by gradual transitions.

Lower Devonian. The lower boundary of the Vecherna suite lies along the bottom of banded siliceous limestones. This suite is relatively extensive and consists of gray thick-bedded granular limestones with interbeds of organogenic-clastic varieties. The thickness is 150-180 m. Among the brachiopods of the suite, characteristic Lower Devonian species are found: Gypidulina optata (Barr.), Eospirifer irbitensis (Tschern.), Uncinulus irbitensis (Tschern.) along with the Lower Eifelian Nudirostra strajeskiana (Vern.), Punctatrypa münieri Grünew and the Eifelian species Spinatrypa tascanensis (Nal.) and Atrypa kolymensis Nal. In addition to the brachiopods there are also tabulates (chiefly Eifelian). In the western European sections, in the upper portions of the Lower Devonian, there are also considerable numers of Middle Devonian species.

For a more precise definition of the boundary between the Upper and Lower Devonian in the international scale, we regard the age of the Vecherna suite as Lower Devonian.

Middle Devonian. In the upper part of the section the deposits of the Vecherna suite are

replaced by rocks of the Middle Devonian Pelosska suite, consisting of dark gray calcareous-argillaceous shales with interbeds of platy limestones. The lower boundary of the suite lies at the level of the black shales in the section. The Pelosska suite contains rare brachiopods of the species Acrospirifer (?) minor Rzon. The thickness of the suite does not exceed 150 m.

The age of the Pelosska suite is considered to be Lower Eifelian, on the basis of its stratigraphic position, since it is overlain by the Urul'tun suite with Upper Eifelian fauna.

The Urul'tun suite consists of gray-green marls and argillaceous limestones filled with brachiopods and occasional tabulates. The lower boundary of the suite follows the greenish marls in the section. The thickness is 100-200 m.

Among the brachiopods of the Urul'tun suite are the upper Eifelian species: Elythyna ex gr. salairica Rzon., Elytha cf. pseudoaculeata Rzon., Acrospirifer cf. frequens (Bubl.), A. subgregarius omulevskiensis Rzon. and Paeckelmania sp. et al. The tabulates are represented by the Eifelian species Favosites aff. robustus Lecompte, F. bystrovi Janet., F. aff. graffi Paetz. et al. The presence of the above fauna identifies the age of the Urul'tun suite as Late Eifelian.

Above the Urul'tun suite, the Voyakh suite has an extremely variegated lithologic composition, including brown, pink and red dolomites, brecciated limestones, anhydrites and occasional gypsums. The isolated interbeds are not sustained, often swelling into lenses and then rapidly thinning out. In no section were any fossil remains found. The maximum thickness is 200 - 210 m. Considering the stratigraphic position of the suite, its age is assumed to be Givetian.

The base of the Upper Devonian section is formed by the rocks of the Salazh suite, consisting of gray and brownish massive granular, sometimes argillaceous, slightly arenaceous dolomites.

Here there are considerable numbers of brachiopods, among which of particular importance are the Lower Frasnian species (common and widespread in Polar basins) Mucrospirifer novosibiricus (Toll.) and the Frasnian species Gypidula comis Owen., Atrypa tubaecostata Paeck. and A. tenuisulcata Wen. Among the tabulates there is an almost complete absence of representatives of the genus Favosites (common in the underlying deposits); the predominant forms are ramose tabulates represented by the "tamnoporidy", which are common in the Frasnian stage. The Salazhsuite is 200 - 450 m thick in various sections.

The Serdar suite is considerably less extensively developed than the underlying ones; it consists of light-colored massive and thick-bedded dolomitized limestones and dolomites, sometimes with thin clay selvages. The presence of Productella speciosa (Hall.) and Crytospirifer whitneyi (Hall.) permits this suite to be assigned to the Famennian stage. The thickness is 230 m.

Carboniferous. Lower Carboniferous deposits were encountered in only one section along the Krasivy creek. They consist of black thin-bedded calcareous-argillaceous shales with interbeds of gray organogenic-clastic limestones (0. 3-0. 5) containing the Tournisian brachiopods Linoproductus ex gr. cora M'Coy and Dictyoclostus ex gr. semi-reticulatus (Mart.) and the foraminifera Hyperimina moderata Malakh., H. vulgaris var. minor Raus, and some others. The visible thickness is 150-170 m.

From the above brief description of the section through the Paleozoic of the central part of the Omulev Mountains, it will be seen that this region is one of the few in which there is a wide occurrence of Paleozoic formations comprising the Kolyma central massif, from the Middle Ordovician through the Lower Carboniferous. The extensive development of the various carbonate rocks and the almost complete absence of terrigenous rocks must be regarded as a characteristic feature of the section. Where terrigenous rocks do occur, they are usually represented by clay shales and extremely rarely by sandstones (Omulev suite). Coarse clastic formations are encountered only at the bottom of the Ordovician section, in the form of a thin packet of conglomerates.

The individual suites of the Ordovician and Lower Silurian, as distinguished in the section, are joined by gradual transitions and on the whole do not change in composition and width for a distance of almost 100 km.

By detailed study of the thicknesses of the Upper Silurian it was possible to establish that they decrease slightly northeastward but with completely maintaining their lithologic composition. The Devonian deposits are more variable in composition and thickness. The Lower Carboniferous unfortunately was studied in only one section, so that it it extremely difficult to estimate its changes in area.

TECTONICS

The Cherskiy uplift (with the Omulev Mountains in its southwestern portion) is a marginal southern extension of the Paleozoic rocks of the Kolyma central massif. On all sides the uplift is bordered by faults, along which the Paleozoic deposits adjoin the Mesozoic rocks filling the Darpir and Omulev grabens. Within the western part of the uplift described in this article the Paleozoic rocks are bent into gently sloping synclinal and anticlinal folds with northwest and equatorial trends, complicated at the flanks by disjunctive dislocations (Figure 4). In the central portion of the region is the Serna syncline, composed of Silurian and Devonian rocks. On the northwest it is bounded by the Bystryy and on the southwest by the Krivun anticline; on the south it bounded by the Uochat horst-anticline (formed by rocks of the Proterozoic, whereas the first two are formed by

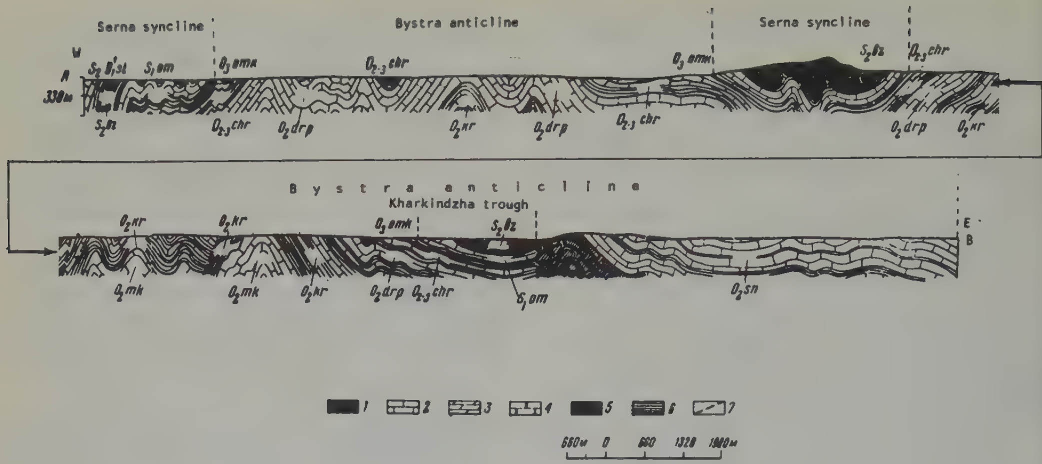

FIGURE 4. Geologic section along line A-B:
Middle Ordovician: O_2^{sn}, Siyen suite; O_2^{mk}, Mokra suite; O_2^{kr}, Krivun suite; O_2^{drp}, Darpir suite; O_2^{chr}, Kharkindzha suite. Upper Ordovician: O_3^{omk}, Omuk suite. Lower Silurian: S_1^{om}, Omulev suite. Upper Silurian: S_2^{bz}, Bizon suite. Upper Silurian-Lower Devonian: S_2^2-D_1^{nl}, Nelyudim Suite. 1 - massive limestones; 2 - limestones; 3 - marls; 4 - dolomites; 5 - massive dolomites; 5 - massive dolomites; 6 - clay shales 7 - faults.

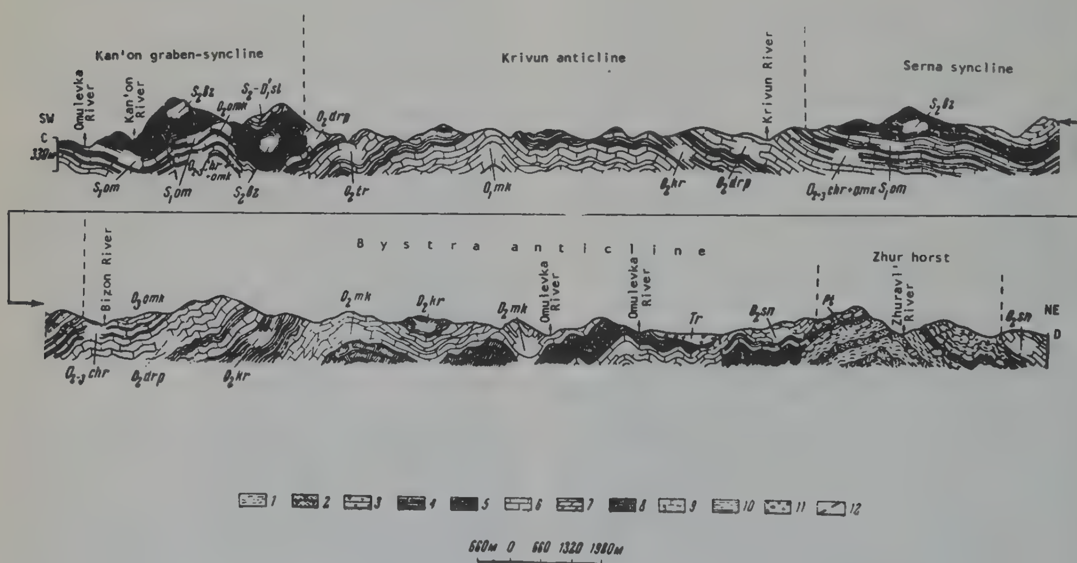

FIGURE 5. Geologic section along line C-D:
PCm, Precambrian; Middle Ordovician: O_2^{sn}, Siyen suite; O_2^{mk}, Mokra suite; O_2^{drp}, Darpir suite; O_2^{chr}, Kharkindzha suite. Upper Ordovician: O_3^{omk}, Omuk suite. Lower Silurian: S_1^{om}, Omulev suite. Upper Silurian: S_2^{bz}, Bizon suite. Upper Silurian-Lower Devonian: S_2^2-D_1^{nl}, Nelyudim suite. 1 - massive limestones; 2 - limestones; 3 - marls; 4 - dolomites; 5 - massive dolomites; 6 - clay shales; 7 - faults.

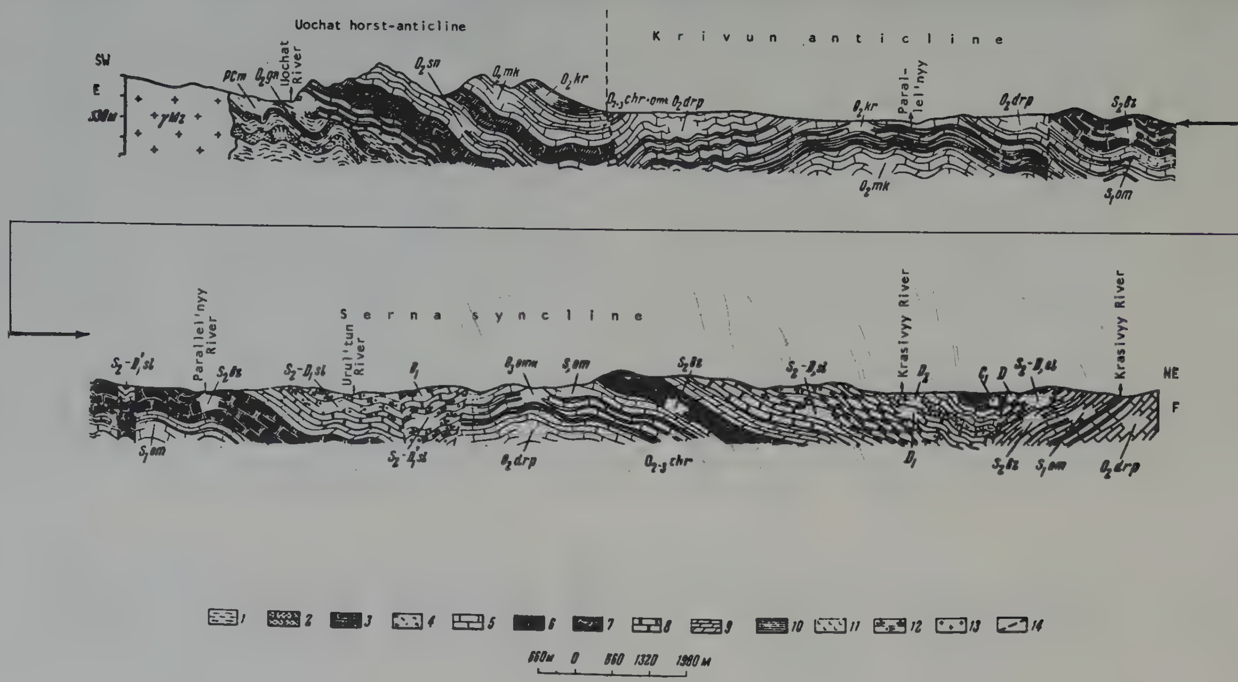

FIGURE 6. Geologic section along line E-F.

PCm, Precambrian. Middle Ordovician: O_2^{gr}, Zhuir suite; O_2^{sn}, Siyen suite; O_2^{mk}, Mokra suite; O_2^{kr}, Krivun suite; O_2^{drp}, Darpir suite; O_2^{chr}, Karkindzha suite. Upper Ordovician: O_3^{omk}, Omuk suite. Lower Silurian: S_1^{om}, Omulev suite. Upper Silurian: S_2^{bz}, Bizon suite. Upper Silurian - Lower Devonian: $S_2^2\text{-}D_1^{lnl}$, Nelyudim suite.

1 - metamorphic schists; 2 - quartzites; 3 - limestones altered to marble; 4 - conglomerates; 5 - limestones; 6 - massive limestones; 7 - massive dolomites; 8 - dolomites; 9 - marls; 10 - clay shales; 11 - anhydrites; 12 - coral limestones; 13 - granitoids; 14 - faults.

Middle Ordovician deposits). West of the Krivun anticline lies the narrow Kan'on graben-syncline. The morphological description of the tectonic forms is best begun from the Bystryy anticline.

The Bystra anticline lies in the extreme northeastern portion of the area under discussion and has a northwestward strike. In the transverse section it is a gently sloping symmetrical fold 30 km wide and 50 km long. The northeast boundary of the anticline is the Ulakhan fault, the southern limit of the Omulev graben.

The core of the anticline contains limestones of the Siyen suite of the Middle Ordovician, forming a gently sloping anticlinal dome some 10-12 km wide. To the east the hinge of the anticline gradually plunges and in the bottomlands of the Razdol'nyy, Bystryy and Alyk creeks the rocks of the Siyen suite form a gently sloping brachysynclinal fold of the second order which complicates the center of the anticline, dipping 40-60° at the flanks. Toward the central portion of the brachysyncline the dip decreases to 20-15°

The eastern part of the core of the Bystryy anticline is broken up by numerous reverse faults bordering a number of structures of the second order. The largest of these is the Zhirskiy horst, composed of Precambrian rocks. This block is almost square in shape, the length and width being approximately 10 km. The reverse faults surrounding it almost at right angles to each other.

In the zone of these faults the rocks of the Ordovician and Precambrian have undergone cataclasis and are partially recrystallized. The Proterozoic rocks comprising the Zhurskiy horst form a quite gently sloping (dipping 30-50° at the flanks) symmetrical domical uplift (Figure 4) complicated at the flanks by small disjunctive dislocations of the strike-slip normal fault type. Along these faults the core of the Bystryy anticline is connected to the flanks.

In the Kharkindzha River basin there are extensive occurrences of rocks of the Middle Ordovician Mokry suite forming the northwest flank of the Bystryy anticline. They form a gently sloping monocline which dips 25-30° north-northeast; to the north they are covered by Mesozoic and Quaternary deposits. The southeast flank of the Bystryy anticline is somewhat more complex in structure. It consists of rocks of the Mokry and Krivun suites of the Middle Ordovician, bent into gently sloping brachysynclinal and brachyanticlinal folds of the second order, which strike northwest (Figure 5). The flanks of these folds dip at angles of 20-30°; their width is from 2 to 10 km.

The largest structure of this type is the Kharkindzha trough in the middle reaches of the Kharkindzha River. It is a rounded, saucer-shaped, symmetrical brachysynclinal fold with a width of approximately 6 km and a length of 8-10 km, filled with Silurian deposits. On its southern and eastern flanks the rocks dip at angles of 30-40°. Toward the center of the trough the angle of dip gradually decreases, and the massive dolomites in the lower section of the Bizon suite are almost horizontal.

South of the Kharkindzha trough, the southern flank of the Bystryy anticline is complicated by a gentle anticlinal fold of the second order, the hinge of which fades out toward the east. Its northwestern flank is buried under the Silurian deposits of the Kharkindzha trough, and its southwestern flank gradually merges into the structural elements of the adjacent large Serna syncline.

The Serna syncline is located in the central portion of the region and extends from southeast of the mouth of the Uochat River northwestward to the Darpir-Yuryakh River. This is a linear symmetrical structure, whose width from northwest to southeast increases from 10-15 to 40 km. The rocks of the syncline include mainly Lower and Upper Silurian deposits, and only to the southeast, where its hinge is buried, does the central portion of the syncline consist of Devonian and Lower Carboniferous deposits.

Throughout the entire Serna syncline the Silurian rocks forming its northeastern flank have a southeastward strike and a dip of 30-40° SW, so that this flank is a normal monocline. Only in the northwesternmost area, in the upper reaches of Omuka creek, are they bent into gently sloping synclinal and anticlinal folds of the second order, with a northwest strike.

In the southeastern part of the Serna syncline its northeastern flank is broken by disjunctive dislocations of almost meridional strike. Here in the fracture zones the dip of the rocks is steeper and reaches 60-80 and even 85°. The c center of the syncline, with a width from 2-3 to 10-15 km, consists of the deposits of the Nelyudim suite and, in the easternmost part, of Devonian and Lower Carboniferous rocks. The latter are crumpled into several symmetrical synclinal and anticlinal folds broken by numerous small disjunctive dislocations. The number and amplitudes of these folds increase with the width and subsidence of the Serna syncline toward the southeast. Conversely, in the northwestward direction there is a gradual disappearance of its hinge, associated with centroclinal closures of the younger sedimentary formations of the Paleozoic, and the small folds in them gradually die out.

The southwestern flank of the Serna syncline is composed of rocks of the Silurian Omulev and Bizon suites, and forms a gently sloping monocline whose dip increases with the distance of the beds from the center of the syncline. In the extreme south of the region the southwestern flank of the syncline is torn by longitudinal faults. This fault zone separates the Serna syncline from the Uochat horst-anticline.

Farther northwest, in the Omulevka River valley and along its left tributaries, the Silurian deposits of the southwestern flank of the syncline

lie conformably on the Upper Ordovician rocks comprising the northeastern flank of the Krivun anticline.

On the map of Krivun anticline has an elongated oval shape with a width of 15-17 km, and extends from northwest to southeast for almost 40 km. Its crest, with a diameter of 9 km, consists of the bedded limestones and shales of the Mokry and Krivun suites. Toward the southeast the hinge of the fold first dips and then, in the gullies of the Poperechniy and Parallel'niy creeks, again disappears. Here the shales and limestones of the Krivun suite form the core of a domical anticline, which is the natural southeastward continuation of the entire structure. The northeastern flank of the Krivun anticline dips gently in the direction of the Serna anticline. Conversely, throughout its entire extent the southwestern flank of the anticline is broken by longitudinal faults into a series of blocks, emphasizing the block-step submergence of the fold toward the southwest. Along this fault the Krivun anticline borders on the Kan'on graben-syncline.

The Kan'on graben-syncline is the westernmost structure of the region; this is a gentle synclinal fold surrounded on all sides by faults and extending from northwest to southeast for 35-40 km, with a maximum width of 8-10 km. The Kan'on graben-syncline frames the Krivun anticline in the west, and in the south, along a fault, it contacts the Uochat horst-anticline. The western boundary of the graben-syncline is the Darpir fault zone the Paleozoic Cherskiy uplift from the In'yali-Debinskiy synclinorium, which is filled with Mesozoic deposits.

The internal tectonic structure of the Kan'on graben-syncline is extremely complex. On the flanks and in the central portion it consists of brachysynclinal folds of the second order, the general trend of their axes coinciding with the orientation of the entire structure. The folds are broken by longitudinal disjunctive dislocations of the norma strike-slip fault type.

The eastern flank of the graben-syncline contains rocks of the Omulev suite, exposed along tributaries. They form a gently sloping minocline dipping some 20-30° to the southwest and broken to the northwest by a longitudinal fault. The center of the Kan'on graben-syncline consists of rocks of the Bizon and Nelyudim suites of the Upper Silurian and bottom of the Devonian, crumpled into folds of the second order. There are no data concerning the structure of the western flank of the graben-syncline, for it was broken by the Darpirskaya fault zone and covered by Mesozoic rocks.

The Uochat horst-anticline is in the south of the region under consideration and is one of the largest anticlinal structures of the Cherskiy uplift. It is an uplift bounded on all sides by faults (Figure 6). Its maximum width is 20 km, and it extends almost 50 km from northwest to southeast, from the Omulevka River valley to the Urul'tun River, where it is buried under the Silurian deposits filling the Serna syncline.

The core of the Uochat anticline consists of Precambrian metamorphis schists, crumpled into symmetrical linear folds whose flanks dip 50-60°, and which are complicated by lesser folds. In the central portion of the structure the metamorphic rocks are broken through by massive biotite granites of Paleozoic age, which on the map have a cigar-shaped outline. The massif was evidently intruded along a fault, as indicated by its shape. The northeastern flank of the structure consists of rocks of the Middle Ordovician, forming a monocline that gradually flattens out to the northeast. The dip of the Ordovician rocks in the northeast flank varies from 40-50° to 25-35°.

In concluding this description of the individual tectonic structures of the Cherskiy uplift, we must dwell briefly on its structural features as a whole. A noteworthy feature is the fact that the Paleozoic deposits forming it are bent into relatively simple, gently sloping symmetrical folds of the brachysynclinal and brachyanticlinal types complicated by smaller folding in the fault zones. Only the Serna syncline as a whole as a linear shape. The plicated structure of the uplift is broken by numerous faults.

Several types of faults are distinguished within the limits of the uplift. The first type consists of the Darpir zone of deep faults, bordering the Cherskiy uplift on the south and southwest. It extends hundreds of kilometers beyond the limits of the region under consideration. The vertical displacement along it is measured in kilometers. The Darpir fault zone intersects the general trend of the Paleozoic structures at a sharp angle and passes along the boundary of the marginal outcrops of the Kalyma central massif and the In'yali-Debinskiy synclinorium, composed of Mesozoic deposits. This was evidently the site of the intrusion of the Mesozoic granitoids.

The second type of disjunctive dislocations includes the longitudinal faults dividing the Cherskiy uplift into separate blocks. They extend over tens of kilometers and apparently do not exceed 2-3 km in amplitude.

The third type encompasses the disjunctive dislocations which are quite common in all the chief tectonic structures of the Cherskiy uplift. It includes longitudinal and transverse faults of the reverse and slip fault types, which range in extent from 1-2 to 15-20 km, with a displacement of several hundred meters, only rarely reaching 1-1.5 km. Most of them, generally maintaining the trends of the structures, cut the flanks of the folded dislocations at acute angles. Faults of this type are usually associated with relatively narrow (up to 10-15 m) zones of cataclasis and recrystallization of the rocks, as well as small folds and, in places, plications. Faults intersecting the

Paleozoic structures at almost right angles are rarely encountered. These are, as a rule, reverse faults with vertical displacements from several hundred meters to 2 km. They frame the Zhurskiy horst and also complicate the structures of the Serna syncline and the Kan'on graben-syncline.

GENERAL CONCLUSIONS

The tectonic history of the Kolyma contral massif has not yet been adequately described. It is particularly difficult to interpret the history of its development in Precambrian and Paleozoic times. Of unquestionable interest from this point of view are the conclusions which can be drawn at the present time concerning the tectonic development of the Cherskiy uplift.

The base of the section through the marginal uplift is a stratum of highly metamorphized mica schists with interlayers of marbles, schistose effusives and micaceous quartzites of the Precambrian. In regard to the character of the Precambrian formations, it may be said that in this region, as in the entire Northeastern U. S. S. R., a régime of high mobility prevailed. This era of geological development concluded with intensive folding over the entire Northeastern U. S. S. R., resulting in the formation of the folded metamorphic basement of the uplift described here.

In the Early Paleozoic there began a major new era in the tectonic development of the region. This embraced an extremely long interval of geological time, from the Middle Ordovician to the Early Carboniferous inclusive. Throughout the territory of the Cherskiy marginal uplift, as in the entire southwest portion of the Kolyma central massif, was formed an extremely wide depression filled chiefly by carbonate formations. The thickness of the latter reaches several kilometers. For this type of geological development Yu. M. Pushcharovskiy has proposed the term "mobile platform".

Three tectonic stages may be distinguished in the development of the depression. The first stage in the territory of the Cherskiy begins with the Middle Ordovician, where it begins with the Riphaean and the Cambrian [sic].[1] At this time were formed thick sequences of carbonate rocks, which contain smaller intergeds of argillaceous material. The sedimentation of the first stage was completed in the Early Silurian, when over a vast area there was formed a relatively thin (up to 250-300 m) stratum of black clay shales. It is characteristic that on the whole the amplitude of the subsidence in this stage of development was apparently quite considerable, as indicated by the thickness of the Ordovician and Lower Silurian deposits within the Tas-Khayakhtakh Range and the Omulev Mountains (with a thickness up to 3. 5 km).

Several different tectonic conditions characterize the second stage in the development of the depression. Throughout its western part this stage began in the Early Silurian, with the formation of strata of white and dark gray dolomites and varicolored marls, and ended in the Early Devonian with the formation of a packet of black clay shales and limestones. The nature of the Upper Silurian and Lower Devonian deposits indicates that during this stage at various times the basin became shallower, shown by the occurrence of varicolored rocks.

The thickness of the Upper Silurian and Lower Devonian deposits in the western portion of the Kolyma central massif is extremely variable: within the Tas-Khayakhtakh uplift it is 2500-3000 m, and in the Cherskiy uplift it is 800-1500 m. It must also be pointed out that within the Cherskiy uplift, the subsidence of its southwestern part was more intensive during this stage of development, and the thickness of the Upper Silurian and Lower Devonian decreases by almost half — from 1300 to 800 m — from southwest to northeast.

It is likely that in this stage there began to be a sharper separation of the individual depressions; within each depression there were more intensively subsiding areas.

The third and last stage in the development began with the Middle Devonian and lasted through the Early Carboniferous. This period of geologic time saw frequent changes in the conditions of sedimentation. Dolomites were formed in the depressions, as were variegated green and rose marls, anhydrites and gypsums, replaced higher in the section by black clay shales. Over relatively small distances, both within the Cherskiy uplift and, apparently, in the other marginal uplifts, there was a sharp change in the thicknesses of the individual suites and beds. This feature of the tectonic history during the third stage of development of the mobile platform appears to indicate an intensification of the tectonic movements with which the internal differentiation of the individual depressions was associated. The total thickness of the Paleozoic deposits in the Cherskiy uplift is 6000-6900 m.

In the Middle and Late Carboniferous sedimentation did not occur in the area of the Cherskiy uplift. At the same time the Permian deposits in the Argatas Range, in the northern part of the uplift, were deposited unconformably

[1]Translator's note: this is the literal translation of the Russian, which probably contains a misprint.

on the underlying Paleozoic formations. Hence it may be assumed that formation of the principal currently existing folded structures probably occurred during the Middle and Late Carboniferous. Apparently the principal discontinuous faults bordering the Cherskiy uplift on the south and southwest were also formed then.

Thus by the Permian the formation of the folded structure of the marginal uplift, like that of the entire Kolyma central massif, was essentially completed.

Throughout its entire Mesozoic history the Cherskiy uplift reacted to tectonic movements, chiefly by the formation of individual horsts and grabens. Apparently the intensive Mesozoic tectonic movements within the marginal uplift occurred in the time from the Late Triassic to the Middle Jurassic, when to its southwest there began the formation to the In'yali-Debinskiy synclinorium, which is the most deeply subsided portion of the Yana-Kolyma megasynclinal zone. The boundary between the Cherskiy uplift and the In'yali-Debinskiy synclinorium followed the Darpir deep fault zone with which the injection of large granitic intrusions was apparently associated. The later Mesozoic and Quaternary tectonic movements, embracing the entire Kolyma central massif, led to the further complication of the block-folded structure of the Cherskiy marginal uplift and to the formation of large basins.

REFERENCES

1. Kropotkin, P. N. and N., and N. P. Kheraskov, Tektonika Severo-Vostoka Azii. [TECTONICS OF NORTHEAST ASIA]: Tr. XVII ses. Mezhdunar. geol. kongr. t. 2, 1937.

2. Kropotkin, P. N., and Ye. T. Shatalov, Ocherk geologii Severo-Vostoka SSSR. [OUTLINES OF THE GEOLOGY OF THE NORTHEASTERN USSR]: ONTI, 1936.

3. Nikolayev, A. A., Stratigrafiya i tektonika Omulevskikh gor. [STRATIGRAPHY AND TECTONICS OF THE OMULEVSKIYE MOUNTAINS]: Materiali po geol. i iskop. Severo-Vostoka SSSR, Vyp. 12, 1958.

4. Novikov, S. V., and P. I. Skornyakov, Dokembriy i paleozoy Okhotsko-Kolymskogo kraya. [PRE-CAMBRIAN AND PALEOZOIC DEPOSITS OF THE OKHOTSK-KOLYMA REGION]: ONTI, 1936.

5. Obruchev, S. V., Materialy po tektonike Severo-Vostochnoy Azii. [MATERIALS ON THE TECTONICS OF NORTHEAST ASIA]: Probl. sov. geol., t. 3, No. 6-7, 1934.

6. Obruchev, S. V., Tektonika Severo-Vostochnoy Azii. [TECTONICS OF NORTHEAST ASIA]: Tr. XVII ses. Mezhdunar. geol. kongr., t. 5, 1937.

7. Pushcharovskiy, Yu. M., Skhema tektonicheskogo rayonirovaniya Severo-Vostoka SSSR. [TECTONIC REGIONALIZATION OF THE NORTHEASTERN USSR]: Dokl. Akad. Nauk SSSR, t. 105, No. 5, 1955.

8. Pushcharovskiy, Yu. M., O tektonike Severo-Vostoka SSSR. [TECTONICS OF THE NORTHEASTERN USSR]: Byull. Mosk. o-va ispyt. prirody, otd. geol., t. 3, No. 5, 1956.

9. Simakov, A. S., O krupnom razome v basseyne r. Kolymy. [THE LARGE FAULT IN THE KOLYMA RIVER BASIN]: Materialy po geol. i polezn. iskop. Severo-Vostoka SSSR, No. 5, 1949.

10. Snyatkov, L. A., and B. A. Snyatkov, Verkhoyano-Chukotskaya skladachaya oblast'. [VERKHOANSK-CHUKOTSK FOLDED REGION. In the book, GEOL. STROYENIYE SSSR (GEOLOGICAL STRUCTURE OF THE USSR)]; T. 3, Gosgeoltekhizdat, 1958.

11. Trushkov, Yu.N., Geologicheskiy ocherk basseyna r. Omulevki. [GEOLOGIC SKETCH OF THE OMULEVKA RIVER BASIN]: GONTI, 1938.

Institute of Geology of the Academy of Sciences
U. S. S. R. Moscow

Received July 4, 1959

THE NATURE OF THE RED AND GREEN COLORS OF THE ROCKS OF THE MESOZOIC AND CENOZOIC REDBED FORMATIONS IN CENTRAL AND SOUTHERN KAZAKHSTAN[1]

by

V. N. RAZUMOVA

The nature of the red color in red arid formations [13, 15] is up to the present time still far from clear. But the majority of investigators attribute the change from green to red colors to the oxidation of the ferrous forms of iron [3a, 14, 16, 18 etc.].

In order to throw some light on this problem, we have studied three genetically different types of parageneses of red, green and gray rocks of Cretaceous and Tertiary age in the western part of Central and Southern Kazakhstan: an association of green-colored rocks with red eluvium, an association of red-colored rocks of arid formations with primary green-colored rocks, and an association of the same red-colored rocks with secondary green-colored rocks. We shall discuss these three associations in order.

a) Association of Green-Colored Rocks with Red Eluvium

South of the 48° parallel, in the northern margin of the Chuy syneclise and in the foothills of the Bol'shoy Kara-Tau Range, there is an extensive development of modern red-colored eluvium. Here it occurs on the slopes of gullies and chinks[2] which are not covered by a mantle of soil or vegetation, and in places forms a dense cover creating a false impression of the red-colored nature of the deposits developed here. This phenomenon was once described by B. A. Petrushevskiy [9] and V. A. Vakhrameyev [1]. The thickness of this eluvial mantle is no more than 0. 1 - 0. 2 m. The eluvium is distinguished from the parent rock by its red or pinkish-red color and its briable, brecciated structure.

The eluvium is composed of a loose clayey mass with a microbreccial texture, consisting of loosely adjoining clay fragments and pieces of the parent rock, intermingled with powder-like particles of red ferric oxide. The friable texture and the oxidation of the iron penetrate deep into the rock along the fractures. With depth both the red ferruginous pigment and the veins of broken rock gradually disappear and the clay becomes dense, monolithic and monotonously green, greenish-gray or bluish-white in color. The small thickness of the eluvial cover is apparently due to the fact that in the desert regions of Kazakhstan, according to A. V. Sidorenko [11], only the layer of soil closest to the surface, about 0. 1 m thick, is most intensively heated (up to 30°). Hence the eluvium here does not exceed 0. 1 - 0. 2 m in thickness.

The red eluvium is accompanied by an efflorescence of baked salt, and more rarely by a layer of loose, fine-grained gypsum sand. The gypsum sand layer occurs at the boundary between the eluvium and the parent rock, whereas the baked salt blooms form white crusts on the hilly, fractured surface of the eluvium. Thus the formation of red eluvium is in places accompanied by a process of salinification. More rarely the red eluvium is accompanied by a powdery coating of manganese hydroxides (Beleuty River). In the more southern areas of Kazakhstan, red eluvium of a similar type has been described by A. V. Sidorenko [11], on the sulfur hummocks of the Central Kara-Kum. Here the light-gray sandstones also grade at the surface into red and pinkish-red sandstones.

The red eluvium is not developed everywhere, but only where there are exposures of argillaceous rocks with a greenish or grayish tint in their color — that is, rocks whose composition includes iron-containing clay minerals of the montmorillonite and illite groups. The selective development of the red eluvium is especially clear along the Beleuta River and the Bozingen gully.

Here the red eluvium is developed on the deposits of the Turonian and Santonian stages, represented by interlayered kaolinte, illite-kaolinite and montmorillonite-kaolinite clays and clayey siltstones with a white, gray or

---

[1]Priroda krasnykh i zelenykh okrasok porod krasnotsvetnykh formatsiy Mezo-Kaynozoga Tsentral'nogo i Yuzhnogo Kazakhstana.

[2]Translator's Note: chinks are border scarps on the Ustyurt Plateau.

bluish-white color. The red eluvium, however, does not form a solid mantle, but is found only on the interlayers of clay and clayey siltstones that are colored bluish and greenish-gray; on the gray and white clays and siltstones the red eluvium is lacking. From this it may be concluded that the occurrence of a red ferruginous pigment in the eluvial layer is due to the presence in the rock of a clay component which gives the kaolinite clay its light bluish or greenish color. In this case such minerals will be iron-aluminum montmorillonite and illite.

In the area of the Chuy syneclise and the Kara-Tau Range, the red eluvium occurs on rocks of Cretaceous and Tertiary age and on the green argillaceous rocks of the ancient weathering crust.

It is of interest to note that the red eluvium is developed not only on rocks composed entirely of iron-containing clay minerals. It also forms on rocks in which these minerals are present only as admixtures.

The mineral composition of the eluvium and the parent rocks is exactly the same, except that the red eluvium is enriched by a red ferruginous pigment. For example, the red eluvium on the greenish-gray illite clays of the Aral suite on the western slope of Mt. Ulutau has, like the parent rock, an illite composition, whereas the pinkish-red eluvium on the bluish-white illite-kaolinite clays of the Turonian-Santonian deposits on the Beleuty River is also illite-kaolinite in composition. The identity of the mineral composition of specimens of green-colored argillaceous rocks and their red eluvium is confirmed by chemical, optical, thermal and X-ray analysis.

Thus mineralogical studies have shown that the red eluvium is distinguished from the parent rock only by its content of a red ferruginous pigment, whereas the silicate part of the rock, composed of minerals of the montmorillonite or illite groups, remains unchanged. Moreover chemical analysis (Table 1) shows clearly that the ocherous coloring of the eluvial layer is not due to oxidation of the iron, since the content of FeO in the parent rocks is very small and differs little in the transition from the parent rock to the eluvium. Inasmuch as the amount of Fe_2O_3 in the transition from the parent rock to the eluvium in the section along the Beleuta River increases sharply, it must be supposed that the occurrence of ferruginous pigment here is due not to the decomposition of the clay aggregates, but to iron brought in from outside. Apparently the iron-containing clay minerals of the montmorillonite and illite groups are effective precipitating agents for the iron. It is known that the minerals of the montmorillonite group irreversibly adsorb heavy metals. Moreover since the adsorption capacity of montmorillonite greatly exceeds that of kaolinite (by about 20 times), the iron carried into the eluvial layer is precipitated in rocks with a high content of illite or montmorillonite, but does not remain in rocks of kaolinite composition (Beleuta River section).

The process of ocherization of the eluvial layer is similar to the process of salting out. According to A. F. Tyulin and T. A. Malomakhova [10], the formation of a film of gel on any mineral occurs not only in the weathering of the surficial layers, but also by adsorption from the surrounding solutions of readily soluble iron salts, which are firmly attached in the form of ferric compounds.

The formation of red low-water iron oxides in the eluvium is apparently due to high temperature and a high concentration of salts [3]. The temperature is the reason for the degree of hydratation of the iron oxides, since the red coloration is characteristic of rocks of hot regions. This statement is confirmed also in the western margin of the Kazakh shield, and especially south of the 48° parallel (the approximate boundary of the dry steppes and the semidesert), where there is red clayey eluvium, whereas farther north the eluvium becomes brown (in the basins of the Kara-Turgay and Sary-Turgay Rivers). Both the red and the brown eluvium are accompanied by efflorescence of baked salt.

b) Association of Red-Colored Rocks of Arid Formations with Primary Green-Colored Rocks

The red colors in the complex of deposits studied here are encountered primarily among continental deposits of subaerial and temporarily subaqueous origin, although they sometimes appear among marine deposits.

Under marine conditions the red colors gravitate primarily toward littoral and deltaic facies [12]. Primary green colors, on the other hand, are characteristic of rocks formed under stable subaqueous conditions and are also observed in marine and continental deposits.

In the red-colored littoral facies of the Paleogene marine deposits of the Southern Mugodzhar and the Bol'shoy Kara-Tau Range, the ferruginous pigment is primary and chemogenic. In thin sections it can readily be seen that the iron oxides form very small accumulations in the greenish-gray beidellite clay, penetrating the entire clayey mass of the rock, and that the very thin ferruginous pigment also encompasses the completely fresh and undecomposed grains of glauconite. Hence the process of pigmentation of the rock with iron oxides has taken place without decomposition of the glauconite and beidellite. If the ferruginous

TABLE 1

Iron Content (Ferrous and Ferric) in Paired Specimens of Red and Green Clays and Argillites

Nature of deposit	Age	Area	Rock	Specimen No.	Content of fraction < 0.001 mm: Fe_2O_3	Content of fraction < 0.001 mm: FeO	Mineral composition of clay fraction
Modern red eluvium	Lower & Middle Miocene	Mt. Ulutau (Mt. Keks-Zhugurchuk)	Red eluvium Green-gray clay	97-3 97-1	6.76 7.65	0.20 0.14	Illite
	Turonian-Santonian	Beleuty R.	Red eluvium Greenish-white clay	237/56 236/56	9.96 3.15	0.27 0.56	Kaolinite Illite
Red continental deposit	Middle & Upper Miocene	Supil'say, Southern Urals, Or'-Ileks interfluve	Red-brown clay loam Green-gray clay loam	38-1 38-2	6.15 5.65	0.43 0.29	Illite
	Upper Oligocene	Chu R., lower reaches	Red clay Green clay	261/52 205/52	8.62 8.05	0.31 0.42	Illite (montmorillonite)
	Middle Oligocene	Dulgaly-Zhilanchik R.	Red clay (slightly ocherous) Green clay	533/56 534/56	9.05 8.89	0.54 0.54	Illite
		Sarysu R., Cape Ayak-Kassaun	Red-brown clay Green clay	51/57 52/57	— 4.56	— 0.96	Illite
	Turonian-Santonian	Bol'shoy Kara-Tau: Koshata village Kyzyl-Dzhar	Red clay Green-gray clay	81-1 8	5.00 [6,7]	0.34	Beidellite
		Bol'shoy Kara-Tau: Koshata village Atabay village	Red clay Green-white clayey sand	81-1 22-3	3.72 [6,7]	0.28	Beidellite (Rocks subjected to secondary leaching)
		Bol'shoy Kara-Tau: Chaga R.	Red clay Dirty white clay	734-6 734-8	5.03 3.87	0.14 0.29	Beidellite (Rocks subjected to secondary leaching)

Table 1, (continued)

Nature of deposit	Age	Area	Rock	Specimen No.	Content of fraction <0.001 mm		Mineral composition of clay fraction
					Fe_2O_3	FeO	
Red continental deposits	Aptian-Neocomian	Bol'shoy Kara-Tau Atabay village	Red clay Light bluish-green clay	762-5 762-6	10.27 5.47	0.47 0.82	Illite
		Southern Urals Orskaya depression	Red clay Green clay	107-1 107-2	11.60 5.60	1.15 0.86	Illite Montmorillonite
Marine deposits	Middle & Upper Eocene	Southern Mugodzhars	Cherry-red clay Green-gray clay	8-196 8-19a	13.79 7.00	0.29 0.29	Beidellite (illite)
	Riphaean	Kaluga (drill hole 32)	Cherry-red argillite Green argillite	32-2 32-1	4.29 2.89	2.87 3.23	

pigment were due to decomposition of the argillaceous aggregates, the glauconite would have been the first to be decomposed.

In continental red-colored deposits it is much more difficult to determine the nature of the red ferruginous pigment, since it is frequently very thin and closely resembles the pigment derived from decomposition. Chemical analysis, however, clearly shows (Table 1) that the change from green coloration to red is here, as in the eluvium, not due to oxidation of the iron-containing minerals present in the rock. This follows from the following data: 1) the content of FeO in the transition from green to red rock does not change, and in a few particular cases is even higher in the red rock than in the green (Table 1, sp. 107 - 1 and 107 - 2, etc.); 2) the red and green rocks, if one excludes the ferruginous pigment, have exactly the same mineral composition, so that the transition from green to red rock is not accompanied by any change in the silicate part of the rock; 3) the basic rock-forming components of both the red and green rocks are minerals of the montmorillonite and illite groups, which do not contain ferrous iron.

Since the composition of the rocks studied by us includes almost no ferrous iron, to explain the role of oxidation processes in the formation of the red color we have for comparison taken some specimens of rock with relatively high content of FeO — about 3% — red and green argillites from the Laminarites beds of the Kaluga drill hole (collected by S. V. Tikhomirov). Here, too, however, as will be seen from the chemical analyses (Table 1, sp. 32-1 and 32-2), the same situation occurs: the content of FeO differs very little in the transition from green to red rock, whereas the total amount of ferric and ferrous iron increases. Consequently, even in rocks that are rich in ferrous iron, the transition from green to red color is, in this case at least, not due to oxidation of the iron.

Thus the material we have examined indicates that the change from green to red colors in arid red-colored formations (associations of red-colored rocks with primary green-colored rocks) is not due to oxidation of the minerals present in the rock.

The formation of ferruginous pigment is also not associated with the decomposition of the clay minerals with ferric iron in the lattice, accompanied by a partial transition of the ferric iron from its silicate form to a free form. This follows from the following data: 1) the quantity of Fe_2O_3 in a number of cases increases sharply in the transition from green to red rocks - that is, the Fe_2O_3 is "added" to the green clay; 2) the red-brown Miocene clay loams of the Orskaya depression (collected by A. G. Chernyakhov) were found to contain, among the clay mass pigmented with iron oxides, redeposited glauconite

grains that were completely fresh and undecomposed (Table 1, 38-1 and 38-2).

Thus there is every reason to think that the red ferruginous pigment in continental arid formations, in the red-colored rocks associated with primary green-colored rocks, is not due to oxidation of the iron minerals present in the rock; this pigment is primary, chemogenic, and formed in the process of sedimentation.

Our conclusions agree fully with those of M. S. Shvetsov [14]: "From the many analyses of rocks from red and green formations", he writes, "it is clear that the rocks with a sharp predominance of ferric iron may be colored green, and the rocks that are relatively richer in ferrous iron may be red".

Despite the fact that the transition from green to red color in the rock is not associated with oxidation of ferrous forms of iron, the accumulation of the ferruginous pigment itself (in primary red rocks) is due entirely to an oxidizing medium. Specifically, the ferruginous pigment apparently accumulates in sediments during the oxidation of ferrous iron, in the transformation of biotite clastic material to iron-aluminum illite (and montmorillonite), or its precipitated from solution under the conditions of an oxidizing medium. In a reducing medium neither the ferrous iron liberated in the transformation of biotite into illite, nor the iron carried in by solutions, is accumulated in the sediment, but both are entirely removed. For this reason the rocks formed under reducing conditions have no ferruginous pigment and have a greenish or greenish-gray color characteristic of the clay components of the rock: iron-aluminum illite and montmorillonite. Thus the iron under the conditions of an arid climate is carried not in suspension [12, etc.], but in the form of readily soluble salts, which in an oxidizing medium are simply attached to the sediment in connection with the transition to ferric compounds.

According to what has been said above, red-colored rocks tend to occur in subaerial and subaerial-subaqueous deposits, where an oxidizing medium is frequently created, whereas green-colored rocks occur under constantly subaqueous conditions. Consequently, all other things being equal, the iron liberated in the sedimentary process will be either fixed in the sediment (oxidizing medium) or removed (reducing medium), depending on its oxygen potential. In the first case there will be a formation of red-colored rocks rich in ferruginous pigment, and in the second case the result will be green rocks lacking such ferruginous pigment.

It is interesting to note that the oxygen potential, which has such a clear influence in the process of sedimentation on the behavior of the free iron oxides, should have no important effect on the composition of the silicate part of the rock. Specifically, within a single formation of rock formed either under oxidizing (red) or under reducing (green) conditions and usually composed of the same clay minerals, the lattice will sometimes contain ferric and sometimes ferrous iron. Apparently the conditions which favor the oxidation and reduction of free iron oxides are not at all the same as the conditions required for oxidation and reduction of the iron which enters the lattice of the clay minerals. For this reason there are two processes occurring independently of each other. It may be supposed that the composition of the clay components of the rock is determined primarily by the pH of the medium. According to I. I. Ginzburg [3], the minerals of the illite and montmorillonite groups are formed under slightly alkaline conditions: illite at pH = 9. 5 - 7. 8 and montmorillonite at pH = 8. 5 - 7. 0.

c) Association of Red-colored Rocks of Arid Formations with Secondary Green-colored Rocks

According to current conceptions, secondary green colors in rocks are formed from primary red-colored rocks by the action of ground waters [2, 5, 19]. In the red-colored formations studied by us, this process is especially widespread in the Turonian-Santonian deposits on the southwestern slopes of the Bol'shoy Kara-Tau Range, in areas which during the Cenozoic underwent the most intensive uplift and subsidence. The most intensively reworked rocks are those of the Koturbulak syncline. Here the most highly leached are the water-permeable sandstone layers, whereas the argillaceous beds have retained their primary red color.

As a result of the action of ground waters the hematite pigment went into solution, and the color of the rock changed from red to light-colored or vari-colored. The color of the leached rock is dirty white, grayish or greenish. Despite these considerable fluctuations, all the leached rocks contain approximately the same amount of Fe_2O_3 in the clay fraction. The formation of green color from red is apparently association with the action of calcium carbonate and calcium sulfate waters, since the leaching and green color are frequently observed at the contact with epigenetic carbonate and gypsum concretions.

The red-colored and leached rocks are composed of the same clay minerals, differing only in the amount of Fe_2O_3 in the rock (Table 1). Hence it follows that the silicate part of the rock has not undergone any process of leaching, and only the hematite pigment has been removed. Thus the amount of Fe_2O_3 in the rock drops sharply (Table 1, sp. 762 — 5 and 762 — 6).

The iron removed from the red-colored rock is sometimes fixed in the same leached sands, forming lenses of brown ferruginous sandstones, and part of the dissolved iron is sometimes adsorbed by the silicate part of the rock in situ. The adsorption of the iron by the clay aggregate may sometimes be clearly seen in thin section. For example, in the leached red montmorillonite clay of the Turonian-Santonian deposits of the Chaga River, against the leached ground mass of the rock one may discern areas with an intensive grass-green color. These are frequently located in the sandy interlayers — that is, in the areas most highly penetrable to solutions.

The iron adsorption capacity of the iron-aluminum montmorillonite and illite may apparently change considerably. Hence the iron-aluminum clay minerals may adsorb iron from solution in the ferrous and, perhaps, in the ferric form (the content of FeO increases within a fraction of a percent) and absorb it in different amounts. According to A. I. Perel'man [8], in places the iron merely goes from one form to the other ($Fe_2O_3 \rightarrow FeO$) without migrating. Here the red color is replaced by green.

CONCLUSIONS

The above data show that in red-colored arid formations the transition from green to red rocks cannot be explained by oxidation of the ferruginous minerals contained in the rock (not to mention the change from the silicate form of ferric iron to free form). The green color here is due to the presence in the rock of iron-aluminum clay minerals of the illite and montmorillonite groups, frequently containing only ferric iron in the lattice, whereas the red color is due to the enrichment of the rock in red ferruginous pigment. V. D. Keller [17] and D. V. Nalivkin [6] also state that the green color of many sedimentary rocks derives from minerals of the illite and montmorillonite groups.

The red ferruginous pigment accumulates in red rocks in the process of sedimentation, apparently as a result of the oxidation of FeO as the biotite clastic material is altered to illite and montmorillonite, in the decomposition of other iron-containing minerals (pyroxenes, hornblendes and epidote) and as a result of the adsorption of iron from solution. Moreover the green color is due either to the primary absence of ferruginous pigment associated with the formation of the rock under reducing conditions (primary green-colored rocks), or with its later solution and removal (secondary green-colored rocks). In the removal of the ferruginous pigment part of the dissolved iron is sometimes adsorbed by the clay aggregate in the form of ferrous and, perhaps, ferric iron.

The behavior of the ferruginous pigment is independent of the silicate part of the rock — that is, it is accumulated or removed without affecting the silicate components, so that the red and green rocks within the same formations are composed usually of the same clay minerals. Apparently the conditions favorable to the oxidation and reduction of free iron oxides in no way correspond to the conditions required for the oxidation and reduction of the iron contained in the lattice of minerals of the illite and montmorillonite groups.

Since the red and green rocks differ mineralogically only in the presence or absence of red ferruginous pigment, the primary and secondary nature of the red and green colors may be determined only by geologic methods.

It is interesting to note that the red-colored rocks of the red arid formations described here in the process of metamorphism apparently were transformed into micaceous rocks of biotite composition. According to D. Zh. Flott (cited by Ye. V. Pavlovskiy - [7]), the original rocks of the Moyn series (Scotland) were red, and during their later metamorphism the ferruginous substance of these rocks entered into the composition of the biotite. Hence in the metamorphism of red-colored rocks we see a process which is exactly the reverse of the above-described supergene process:

$$\text{biotite} \rightarrow \underset{\text{hematite}}{\text{illite}} \rightarrow \text{biotite}$$

REFERENCES

1. Vakhrameyev, V. A., Stratigrafiya i iskopayemaya flora kontinental'nykh melovykh otlozhe niy zapadnogo Kazakhstana. Regional'naya stratigrafiya SSSR, t. 1. [STRATIGRAPHY AND FOSSIL FLORA OF THE CRETACEOUS CONTINENTAL DEPOSITS OF WESTERN KAZAKHSTAN. REGIONAL STRATIGRAPHY OF THE USSR, Vol. 1]: Izd. In-ta Geol. Nauk Akad. Nauk SSSR, 1952.

2. Geysler, A. N., K voprosu ob okraske pestrotsvetnykh otlozheniy. [ON THE COLOR OF VARI-COLORED DEPOSITS]: Zap. Vses. Mineralog. O-va, Ch. 78, Vyp. 2, 1949.

3. Ginzburg, I. I., Geokhimiya i geologiya drevney kory vyvetrivaniya na Urale. [THE GEOCHEMISTRY AND GEOLOGY OF THE ANCIENT WEATHERED CRUST IN THE URALS]: Tr. In-ta Geol. Nauk Akad. Nauk SSSR, Ch. 2, Vyp. 81, 1947.

3a. Danchev, V. I., Tsvet osadochnykh porod kak odin iz pokazateley usloviy ikh formirovaniya. [THE COLOR OF SEDIMENTARY ROCKS AS ONE INDEX OF THE

CONDITIONS OF THEIR FORMATION]: V. Sb. Vopr. Mineral. Osad. Obr., Izd. L'vovsk. Un-ta, Kn. 3 - 4, 1956.

4. Kukolev, G. V., Khimiya kremniya i fizicheskaya khimiya silikatov. [THE CHEMISTRY OF SILICA AND THE PHYSICAL CHEMISTRY OF SILICATES]: Promizdat, 1951.

5. Miropol'skiy, L. M., O krasnotsvetakh tipa "red beds" v permskikh otlozheniyakh srednego povolzh'ya i prikam'ya i ikh okrashennosti. [RED-COLORED ROCKS OF THE "RED BEDS" TYPE IN THE PERMIAN DEPOSITS OF THE MIDDLE VOLGA AND THE KAMA RIVER AREAS AND THE NATURE OF THEIR COLORING]: Doklady Akad. Nauk SSSR, t. 41, No. 8, 1943.

6. Nalivkin, D. V., Ucheniye o fatsiyakh. [STUDY OF FACIES]; Izd-vo Akad. Nauk SSSR, 1956.

7. Pavlovskiy, Ye. V., Geologiskaya istoriya nagoriy shotlandii v dokembrii i nizhnem paleozoye i rol'glubinnykh razlomov. [THE GEOLOGIC HISTORY OF THE SCOTTISH UPLANDS IN THE PRE-CAMBRIAN AND THE ROLE OF DEEP FRACTURES]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 7, 1958.

8. Perel'man, A. I., Sledy bylykh vodonosnykh gorozontov v osadochnykh porodakh. [VESTIGES OF FORMER WATER-BEARING STRATA IN SEDIMENTARY ROCKS]: Priroda, No. 6, 1958.

9. Petrushevskiy, B. A., Struktura turgayskoy vpadiny. [THE STRUCTURE OF THE TURGAY BASIN]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 4, 1939.

10. Tyulin, A. F. and T. A. Malomakhova, Srvanitel'noye izucheniye pazlichnykh sposobov pokrytiya grubodispersnykh glinistykh mineralov polutornymi okislami. A COMPARATIVE STUDY OF VARIOUS METHODS BY WHICH COARSELY DISPERSED CLAY MINERALS ARE COATED WITH SESQUIOXIDES]: Pochvovedeniye, No. 11, 1948.

11. Sidorenko, A. V., O psevdogidrotermal'nykh protsessakh v mestnostyakh s pustynnym klimatom. [PSEUDOHYDROTHERMAL PROCESSES IN LOCALITIES WITH AN ARID CLIMATE]: Doklady Akad. Nauk SSSR, t. 84, No. 6, 1952.

12. Strakhov, N. M., Zhelezorudnyye fatsii i ikh analogi v istorii zemli. [IRON-ORE FACIES AND THEIR ANALOGUES IN THE HISTORY OF THE EARTH]: Tr. In-ta Geol. Nauk Akad. Nauk SSSR, Vyp. 73, 1947.

13. Strakhov, N. M., Tipy osadochnogo protsessa i formatsii osadochnykh porod. [TYPES OF SEDIMENTATION PROCESSES AND FORMATIONS OF SEDIMENTARY ROCKS]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 5 - 8, 1956.

14. Shvetsov, M. S., Petrografiya osadochnykh porod. [PETROGRAPHY OF SEDIMENTARY ROCKS]: Gosgeolizdat, 1948; 1958.

15. Yanshin, A. L., Krasnotsvetnyye formatsii. [RED-COLORED FORMATIONS]: BSE, t. 23, 1956.

16. Dorsey, G. E., THE ORIGIN OF THE COLOR OF RED BEDS. J. Geol. vol. 34, No. 2, 1926.

17. Keller, W. D., ILLITE AND MONTMORILLONITE IN GREEN SEDIMENTARY ROCKS. J. Sediment. Petrol, vol. 23, No. 1, 1953.

18. Tomlinson, C. W., THE ORIGIN OF THE RED BEDS. J. Geol. Vol. 24, 1916.

19. Vickers, R. C , ALTERATION OF SANDSTONE AS A GUIDE TO URANIUM DEPOSITS AND THEIR ORIGIN, NORTHERN BLACK HILLS, SOUTH DAKOTA. Econ. Geol., vol. 52, No. 6, 1957.

Geological Institute of the Academy of Sciences
Moscow

Received May 28, 1959

ON HUMIC COALS AND THE TYPES OF STRUCTURES OF CERTAIN THICK COAL SEAMS OF MESOZOIC AGE[1]

by

V. S. YABLOKOV AND L. I. BOGOLYUBOVA

This article describes and suggests a scheme for the classification of certain thick coal seams of Mesozoic age, discusses some peculiarities in the distribution of the chief types of coals throughout the seams, and characterizes the types of structures of thick coal seams in various deposits.

* * * * *

Out investigation is based on sections through thick coal seams studied in open-pit and shaft mines in the following deposits: the Volchan, Bogoslov, Veselov (eastern slopes of the Middle Urals, Rhaetian-Liassic), Korka, Krasnoselo (Chelyabinsk basin, Triassic), Tkibul', Tkvarchel', (Transcaucasus, Middle Jurassic, Batskian stage), Itatskoye[2] (Middle Jurassic) and Angren[3] (Central Asia, Lower Jurassic) deposits.

The present article will not describe the coals and the structures of the coal seams of each deposit, since this has already been done in a number of papers by various authors: Ya. M. Chernousov, [16], L. I. Bogolyubova [1, 2, 3], G. I. Bushinskiy and L. I. Bogolyubova [4], B. I. Gudzhedzhiani [7], A. I. Ginzburg [6], O. D. Rusanova [12] and others.

Yu. A. Zhemchuzhnikov [9], in characterizing the coals of Rhaetian-Liassic age, wrote: "In comparison to the Paleozoic coals, these have a number of positive and negative features. Among the latter is the almost complete absence of spore coals. They are partially replaced by pollen coals. But the latter are very limited in distribution and, even when the pollen casing is highly saturated, do not have the character of durains. They are more likely to be clarains or very similar duroclarains. The Lower Jurassic in particular is characterized by the presence of purely fusain-xylain types of coal (Southern Fergana), which also frequently occurs in Upper Jurassic coal seams".

Our studies agree with Yu. A. Zhemchuzhnikov's general concepts, and also provide a more detailed characterization of the material composition of the coals, from the standpoint of their original material and the nature of their alteration, and thus provide a basis for a more precise classification of the types of coals composing the coal seams of Mesozoic age.

On the basis of our factual data we have adopted the terminology of the microcomponents shown in Table 1. In this table the microcomponents are divided into class and subclass by their material composition, into type and subtype by the degree of preservation of their structure, and into form by the parts and tissues of plants forming the original material. This terminology represents a certain generalization based on the existing classifications by Yu. A. Zhemchuzhnikov [8], A. I. Ginzburg [6] and the classification adopted by the all-Union Conference of Coal Petrographers in 1956 and used by I. E. Val'ts [5]. By using this terminology for the microcomponents, petrographic studies can be made with any degree of detail, depending on the purpose of the study and the nature of the material to be investigated.

Nevertheless the conceptions of telinite and collinite must be more precisely defined. According to the internation classification and the classification adopted by the All-Union Conference of Coal Petrographers, structureless vitrain is listed as collinite because in reflected light it is indistinguishable from collinite.

The present authors believe (and have so stated in this article) that telinite should include all the gelified formed elements, including structureless vitrain — that is, the microcomponents which are the products of incomplete decomposition of the plant material in the

---

[1] O gumusovykh uglyakh i tipakh stroyeniya nekotorykh moshchnykh plastov Mezozoyskogo vozrasta.

[2] Specimens obtained from P. P. Timofeyev (Institute of Geology of the Academy of Sciences of the U.S.S.R.).

[3] Specimens and sections, treated microscopically, obtained from A. I. Ginzburg (All-Union Institute of geology).

Table 1

Names of Microcomponents

Material composition		Degree of preservation of structure		Original material of plant parts and tissues
Class	Subclass	Type	Subtype	Form
Gelified	Vitrinite	Telinite	Xylain, xylovitrain, structured vitrain, structureless vitrain	Wood and parenchyma
			Vitrainal rounded-angular and net-like bodies	Partly fungus remains
		Collinite	Transparent ground mass	Not determinable
	Semivitrinite	Semitelinite	Semixylain, semixylovitrain, structured semivitrain, structureless semivitrain	Wood and parenchyma
			Semivitrainal rounded-angular and net-like bodies	Partly fungus remains
		Semicollinite	Transparent ground mass	Not determinable
Fusainized	Semifusinite (brown)	Semifusinite-telinite	Semixylaino-fusain	Mainly wood
			Semifusainal rounded-angular bodies	Partly fungus remains
		Semifusinite-collinite	Semitransparent ground mass (opaque matte)	Not determinable
	Fusinite	Fusinotelinite	Fusain, xylofusain, xylovitrofusain, vitrofusain	Mainly wood
			Fusainal rounded-angular bodies	Partly fungus remains
		Funinocollinite	Nontransparent ground mass (opaque matter)	Not determinable
Lipoidal	Cutinite	–	–	Spores, pollen, cuticle
	Suberinite	–	–	Cork Tissue
	Resinite	–	–	Resinous bodies

process of gelification. The term collinite should refer to microcomponents which are the result of complete decomposition of the vegetative material in the process of gelification; in coals this includes the various forms of transparent ground mass. The need for such a subdivision of the gelified microcomponents was shown in a complex petrographic and technological study of the coals and a lithologic investigation of the surrounding rocks in the Donets Basin [15, 17, 18], and has also been confirmed in investigations of the coals of other basins (Ye. I. Tarakanova - [14]; L. I. Bogolyubova - [1, 2]; V. V. Kalinenko - [10]). Consequently we should attempt to achieve a method of studying coals in reflected light that will made the greatest possible distinction between structureless vitrain and gelified ground mass, instead of uniting these completely different microcomponents merely because in this case the methods used in investigating the coals are indequate.

From the study of the coals, both macroscopically and microscopically, in section and in horizontal plan showing the distribution of the thick coal seams, it has been possible to determine the chief petrographic properties of the coals of the above-mentioned deposits and to provide a precise classification based on concrete factual data (Table 2). The names of the individual subdivisions in this classification of coals follow the terminology we have adopted for the microcomponents. The groups, classes and types of coals, as may be seen from Table 2 and as follows from their descriptions, are for the most part contained in the material and petrographic classifications of humic coals suggested N. M. Krylova, I. E. Val'ts, A. A. Lyuber and A. I. Ginzburg [11] at the Second Conference on Coal Geology. The petrographic features of the coals are described below.

I. CLASS GELITES
(Clarains and Duroclarains)

The class Gelites combines all the coals characterized by a sharp predominance of gelified microcomponents in various stages of decomposition, from xylain to the ground mass, which must be more than 50%. The solid brown coals and slightly metamorphosed rock gelites, usually bright and semibright, show a conchoidal or semi-conchoidal fracture and a homogeneous, streaked or banded natural structure due to the presence of various amounts of vitrainized plant remains, which are usually unevenly distributed. The mineral admixtures include pyrite, siderite and a greater or lesser amount of clay matter.

According to the degree of preservation of the structure of plant remains and the breaking up of the latter in decomposition during the process of gelification, the gelites are divided into three types: A) gelitotelinites, B) gelitoattrites and C) gelitocollinites.

A. Gelitotelinites consist of accumulations of gelified formed elements, of which the most characteristic of this type are xylovitrains with semi-disintegrated and disintegrated cells, blocky xylovitrains, structured and structureless vitrains and vitrain V. The prodominant inclusions are from 0. 2 to 1 mm in size, but there are also larger inclusions 1. 5 - 2 mm in size and also entire fragments of stems some 5 to 10 cm long and 2 to 3 cm thick. The stem fragments usually form part of the structured and more rarely structureless vitrain and, represent remains of conifers. Xylainized and fusainized tissues are not characteristic of this type, and the pollen and spore admixtures are small. Collinite and attritic material are present in greater or lesser amounts between the fragments of plant tissues. The content of cuticle and resinous bodies varies.

Depending on the predominant type of plant tissue in the original material, the gelitotelinites are subdivided into two subtypes: a) wood-cellulose and b) parenchyma.

a) Wood-cellulose gelitotelinites consist mainly of individual fragments of stem and stalk tissue, with a predominance of wood-cellulose tissues and smaller amounts of barks, characterized by thick-walled cells. The content of leaf parenchyma is small. Resinous bodies usually form a part, but their amount may vary. The individual tissue fragments are represented by xylovitrain with semi-disintegrated and disintegrated cells, structured and structureless vitrain and sometimes vitrain V. Fusanized tissues are rare. This subtype contains two forms: wood-cellulose gelitotelites consisting of entire fragments of stems which are usually cemented by a small amount of carbonaceous argellite for susinite-attrite coal, and wood-cellulose gelitotelites represented by accumulations of various wood-cellulose tissues.

The macrostructure of these coals is usually banded, and sometimes lanticular-banded from the presence of large inclusions of vitrain.

In its content of mineral admixtures this subtype belongs mainly to the low-ash variety, except for the coals consisting of stems, which belong to the ash variety.

b) Parenchymal gelitotelinites. The composition of these coals contains a large amount of leaves surrounded by cuticle. The cuticle is thin, with and without serrations. The parechymal leaf tissue is highly gelified but has not passed through the liquid stage, and has thus remained in the stage of blocky xylovitrain. Sometimes the leaf tissues contain vascular

Table 2

System of Classification of Humic Coals of Some Thick Coal Seams of Mesozoic Age

Classification unit	Criterion of coal classification	Name of coal											
Group	Nature of Original vegetation	Humolite											
Class	Material composition	I. Gelite (duroclarain)								II. Cutinite (clarodurain, durain)	III. Resinite (clarodurain, durain, liptobiolite)	IV. Fusinite (clarodurain, durain, fusaino-xylain coal)	
Type	Degree of preservation of structure and of dissociation of plant tissues	A. Gelitotelinite				B. Gelitoattrite		C. Gelitocollinite		Gelitocollinocutinite	Gelitocollitoresinite	A. Fusinotelinite	B. Fusinoattrite (micrinite)
Subtype	Original material of plant parts and tissues	a. Wood cellulose		b. Parenchyma		Scarcely determinable		Not determinable		Wood-parenchyma (?)	Mainly wood cellulose (?)	a. Wood cellulose	b. Not determinable
		of stems	of tissues										
Variety	Degree of enrichment with mineral admixtures	Ash	Low-ash	Low-ash	Ash	Low-ash	Ash	Low-ash	Ash	Ash	Ash	Ash	Ash

Micro-scopic features	Lustre	Semibright with small content of dull ground	Semibright	Semi-bright / Semi-dull	Semi-bright / Semi-dull	Semi-bright / Semi-dull	Semidull, dull	Semidull	Semidull, dull	Semidull, dull
	Structure	Coarse-banded	Coarse-banded, banded, rarely streaked	Banded, streaked	Banded, streaked	Banded, streaked, massive	Streaked	Coarse-banded	Banded, streaked	Streaked, massive

cavities filled with resin. In a number of cases the leaves are heaped together in a dense mass forming an aggregate. Sometimes they are sunk into a more or less transparent ground mass, which contains macrospores, single particles of opaque substance, etc. Occasionally between the leaves there is a thin film of clayey matter, so that the coal shows good cleavage and acquires a semi-dull lustre. Along with the leaves, the coal contains stem elements represented by wood and bark tissue. The macrostructure of the coal is usually streaked. This subtype includes low-ash and ash coals of the same petrographic composition.

B. Gelitoattrites are characterized by a predominance of tiny fragments of tissue less then 0.2 mm in size, represented mainly by xylovitrain, vitrain and rarely xylain. The shapes of the individual particles of the attrite vary greatly; they may be lenticular, banded, subangular and rounded. The outlines of the particles are sometimes clear and sometimes fused. Sometimes, when they are sufficiently decomposed, the individual attrite particles merge into each other where they are in contact, thus forming areas within the coal in which the gelified substance has a denticular structure.

The composition of this coal includes leaf parenchyma, wood-cellulose, bark and mechanical tissues of stems, microspores, cuticle, resinous bodies, and rounded-angular bodies. Along with the small plant remains, this type also includes rare large fragments of the above-mentioned tissues, represented chiefly by structured and structureless vitrain. Fusainized inclusions are few in number. The attritic material and the above-listed formed elements are usually cemented by a lesser or greater amount of transparent ground mass, which is quite clearly distinguished by its darker color. The transparent ground mass includes particles of opaque substance, the quantity of which may vary from very little to considerable amounts, and sometimes includes entire algal plants. The inclusions are distributed unevenly and without order in the coal. The coal lumps usually have a streaked and more rarely banded structure.

This type of coal, in contrast to the gelitotelinite, is characterized not only by more fragmented plant material, but also by the greater degree of its gelification, by its greater amount of microspores and particles of opaque substance and by its lack of remains of the original tissues, so that it is not possible to distinguish the parenchymal and wood-cellulose coals, which are easily identified in gelitotelinites.

The attrite coals, depending on the amount of mineral admixture, represented chiefly by quartz grains and clay matter, fall into two

varieties: a) low-ash and b) ash. In the latter the disintegration of the plant material is due not only to microbiological activity, but also to mechanical breaking up of the plant tissues under swamp conditions in a highly dynamic medium. In its microstructure the coal of the ash variety, in contrast to the low-ash coal, contains more particles of opaque substance and microspores, and macroscopically it is semi-dull.

C. Gelitocollinites. The characteristic feature of this type is a sharp predominance in the coal of the transparent ground mass of collinite, which is the result of complete decomposition of the plant matter in the process of gelification. The collinite substance is usually lumpy, homogeneous or flaky; gelified formed elements are present in very small quantities as lenses and small bands vitrainized wood, fragments of considerably gelified bark, and the remains of cells or mechanical tissues and leaf parenchyma. Fusainized inclusions are few in number. Only in a few isolated cases is the coal enriched with particles of opaque substance and tiny fragments of tissue, whereas in the others there are merely large lenses of semifusinite-telinite and semifusinite. The amount of pollen and spores is not constant and may vary from single inclusions to the upper quantitative limit in the group of gelinites. Cuticle is rarely found; sometimes it is disintegrated and decomposed, forming areas of orange-colored collinite. In a number of cases single algal plants of the genus Pila were encountered in the coal.

The coal lumps are usually semibright and homogeneous or coarse-banded in structure, because of the presence of fragments of vitrainized wood-cellulose, and show typical semiconchoidal fracture. According to their content of mineral admixtures, represented chiefly by grains of quartz and clayey matter, two varieties are distinguished: a) low-ash and b) ash coals. The latter do not differ from the former in their composition of microcomponents but macroscopically they are semidull, with a more-or-less distinct plane fracture.

Coal of the gelitocollinite type is the final product of decomposition of the plant material in the process of gelification and therefore contains very little structured tissues and formed elements in general, so that it is impossible to identify the original material from which the coal was formed.

II. CLASS CUTINITES
(Clarodurains, Cuticular Durains)

The group of cutinites encompasses the coals whose composition includes large amounts of cuticle (more than 50%). Macroscopically they are semidull, usually streaked and sometimes banded. They frequently show good cleavage, and in the horizontal cleavage planes one sometimes observes very thin films of carbonaceous argillite. The microstructure of the coal contains abundant cuticle, whose cavities and filaments are frequently interlayered with thin layers of gelified substance containing individual microspores, resinous bodies, lenses of fusain and other inclusions. The cuticle, with and without denticulation, in rare cases surrounds the leaf parenchyma or stem tissue. Usually it is isolated in the gelified substance as collinite of homogeneous or somewhat lumpy structure. The class of cutinites is represented by one type of coal, gelitocollinite-cutinite. From the nature of cuitcle, it may be thought that the coal was formed from the stems and leaves of plants, so that in its original material this type is represented only by the wood-parenchyma subtype, and in its content of mineral admixtures belongs to the ash variety.

III. CLASS RESINITES
(Clarodurains, Durains and Resinous Liptobioliths)

The peculiar feature of the coals of this class is the predominance of resinous bodies in their composition, amounting to more than 50%. The coal lumps are dull or semidull, with a brown or black-brown color. In the vertical fracture the resinous bodies are black and shiny, and in the horizontal section they appear as dull spots. This coal is typefied by the presence of fairly large lenses of vitrain, giving the coal its coarse banded structure.

Under the microscope it can be seen that the resinous bodies are of various shapes - angular, rounded and lenticular. They range in size from those readily seen by the naked eye to others discernible only under the microscope. Their color also varies, and may change from lemon-yellow to orange. The resinous bodies are usually cemented by a greater or smaller amount of ground mass — collinite, whose color depends on the amount clayey matter it contains. With a low content of clay matter, the collinite has a cinnamon-brown color; when the amount of clay is large, the collinite is dirty yellow. The collinite as a rule has a homogeneous structure. In addition to the resinous bodies, the coal has been observed to contain small amounts of microspores, as well as of fusainized tissue. In the degree of decomposition of its plant tissues, the class of resinites is represented by a single type — gelitocollinite-resinite. The considerable inclusions of resin in the coal, as well as the presence of a large amount of large stem fragments whose wood cellulose contains many resinous bodies, confirms the supposition that this coal originated from wood tissue and places it in the wood-cellulose subtype. The greater part of the resinite coals belong to the ash variety. When there is a very large amount

mineral admixtures, the coal grades into resinous carbonaceous argillites.

IV. CLASS FUSINITES
(Clarodurains, Durains, Fusoxylain coals)

The class of fusinites is characterized by a predominance of fusainized components in the coal, amounting to more than 50%. Macroscopically the fusinites are dull and semidull, massive or streaked, frequently with an earthy fracture. According to the degree of preservation of the tissue structure and its decomposition, two types are distinguished: A) fusinite-telinites and B) fusinite-attrites.

A. Fusinite-telinites are represented by an accumulation of rather large fragments of tissues, stems and branches, consisting of microcomponents of the sub-class semivitrinite, semifusinite and fusinite. Their color varies from reddish brown to brownish black and black. Annual rings can sometimes be seen in the structure of the tissue.

These fragments of altered tissues are usually packed closely together, forming an aggregate. In a number of cases they are separated by lenticular bands of vitrain B, which in some places is surrounded by a homogeneous ground mass of collinite. Microspores, cuticle and resinous bodies are encountered as single fragments in the coal. Only wood tissue has been found in the original material of the coal, so that within the type only one subtype, wood-cellulose coal, can be distinguished. In their amount of mineral admixtures, these coals belong to the low-ash variety. The coal lump is usually black, dull, rather friable, soft and characterized by an earthy fracture.

B. Fusinite-attrites. This coal contains a predominance of small fragments of tissue, belonging to the various microcomponents of the subclass semi-fusinite and fusinite, along with semitransparent and transparent ground mass. Large fragments are very few in number. The tissue fragments are often closely packed together in the ground mass (opaque matter), forming a dense, semitransparent and opaque background, clearly revealing the considerable admixture of microspores, cuticle, individual resinous bodies, plate-like cells of bark tissue, veinlets of transparent ground mass and small inclusions of gelified formed elements. The original tissues of the coal show no traces of any considerable degree of decomposition of the latter. The coals of this type are characterized by a large admixture of mineral substances, so that they all belong to the ash variety. The coal lumps are black, with a brownish-grey shade, dull or semidull, depending on the amount of gelified substance in the coal. The coal has a streaked or massive structure, and an angular fracture with granular surfaces. When the amount of mineral admixtures becomes large, the coal grades into carbonaceous argillite.

CONCLUSIONS

These coal types do not occur in equal amounts in the seams of various deposits, and in each given deposit some have peculiarities in the details of their petrographic structure.

On the basis of a predominance (about 50%) of one type of coal and a considerable content (more than 10 to 20%) of one or two other types, one may distinguish six kinds of structures of thick coal seams (Table III).

Type I - Seams with a predominance of gelitotelinite-wood-cellulose (48%) and gelito-attrite ash coals (29%). To this type belong the seams of the Volchan and Itat deposits. The gelitotelinite coals of the Itat deposit, in contrast to those of the Volchan deposit, contain somewhat larger amounts of mechanical and bark tissues; they have almost no leaf parenchyma and cuticle, whereas the latter sometimes occur in the Volchan coals.

Type II consists of coal seams with a predominance of gelitoattrite low-ash coals (53%) with a considerable amount of fusinite-attrite (23%), such as the coal seam of the Veselov deposit.

Type III contains coal seams with a predominance of gelitocollinite coals (53 to 78%) with large amounts of gelitoattrites and fusino-attrites. This third type includes the coal seams of the Bogoslov deposit and the Chelyabinsk basin.

Type IV is characterized, along with a predominance of gelitocollinite coals (51%), by a considerable content of resinites (24%) and gelitoattrites of the ash variety (14%). This type includes the peculiar seams of the Tkibul' deposit with its resinite coals, which are not found in other seams.

The gelitoattrite coals of this seam, in contrast to those found in the seams of the Bogoslov, Chelyabinsk and Veselov types, contain smaller particles of attrite, the individual particles also showing traces of decomposition, leading to the formation of a denticulated gelified substance which is not characteristic of the coals of other deposits.

Type V embraces seams consisting chiefly of gelitocollinite coals (78 to 96%). An example of this type is the seams of the Tkvarchel' deposit, in which the other types of coal are almost completely absent.

Gelitocollinite coals predominate in the

Table 3

Characteristics of Types of Structures of Thick Coal Seams in Various Deposits

Type of structure of seams	Name of deposit and basin	Content of coal types, in %									
		Gelitotelinite wood cellulose of stems	Gelitotelinite wood cellulose of tissues	Gelitotelinite parenchyma	Low-ash gelitoattrite	Ash gelitoattrite	Gelitocollinite	Gelitocollinite-cutinite	Gelitocollinite-resinite	Fusinotelinite	Fusinoattrite
I. Gelitotelinoattrite	Volchan deposit	5.06	47.96	3.07	4.57	29.33	2.06	1.53	—	0.57	5.84
II. Gelitofusinoattrite	Veselov deposit	5.53	7.03	0.63	52.79	11.09	—	—	—	—	22.93
III. Gelitocollinoattrite	Bogoslov deposit	3.50	—	0.86	22.40	4.44	52.67	1.53	—	0.42	15.53
	Chelyabinsk basin	0.67	1.20	0.26	8.21	5.75	77.80	—	—	0.14	5.97
IV. Gelitocollinoresinite	Tkibul' deposit	1.57	—	4.27	3.00	13.55	51.06	0.99	23.70	—	1.85
V. Gelitocollinite	Tkvarchel' deposit	—	—	—	—	—	95.73	4.27	—	—	—
VI. Fusinotelinite	Angren deposit	—	3.69	—	0.38	0.50	—	—	—	92.76	2.11

Note: The content of the coal type in the deposit was calculated as an average per cent of 4 to 7 sections through coal seams in the open pit or mine, without allowance for the interbeds of rock. In areas where the seams branch out, and in marginal areas, individual sections in regard to the ratios of similar coal types sometimes show important deviations from the ratios of these same coal types in the seam as a whole.

three latter types of seams. In each deposit, however, they show features peculiar to themselves. In the Bogoslov gelitocollinites there is fusainized tissue with an almost complete absence of inclusions, including opaque substance. The Tkibul' gelitocollinites contain almost no fusainized matter, but are rich in microspores and resin; the Chelyabinsk coals, along with spores and cuticle, contain microcomponents of the semifusinite and fusinite subclasses; the Tkvarchel' gelitocollinites, which have no fusainized substance, contain only isolated spores and cuticle.

Type VI includes the seams composed of fusinite-telinite coals (93%), with very low contents of coals of the other types. This includes the seams of the Angren deposit, which Yu. A. Zhemchuzhnikov has distinguished as being characteristic of Early Jurassic coal deposition.

The above-described types of structures of the thick Mesozoic coal seams (relative to the types of coal) reflect the different conditions of their formation. The conclusions regarding these matters, however, must be supported by data on the structure of thick coal seams of Paleozoic and Tertiary age.

REFERENCES

1. Bogolyubova, L. I., O petrogeneticheskikh i khimicheskikh osobennostyakh nekotorykh tipov veshchestva burykh ugley. [PETROGENETIC AND CHEMICAL PROPERTIES OF SOME TYPES OF SUBSTANCES IN BROWN COALS]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 11, 1959.

2. Bogolyubova, L. I., Petrograficheskaya i khimicheskaya kharakteristika nekotorykh tipov ugley Volchanskogo i Bogoslovskogo mestorozhdeniy. V kn. Genezis tverdykh goryuchikh iskopayemykh. [PETROGRAPHIC AND CHEMICAL CHARACTERISTICS OF CERTAIN TYPES OF COALS OF THE VOLCHAN AND BOGOSLOV DEPOSITS. In the book, GENESIS OF SOLID FOSSIL FUELS]: Moscow, 1959.

3. Bogolyubova, L. I., K voprosu o stepenyakh uglefikatsii i stadiyakh ugleobrazovaniya burykh ugley. [ON THE DEGREES OF CARBONIZATION AND THE STAGES IN THE FORMATION OF BROWN COALS]: Doklady Akad. Nauk SSSR, t. 125, No. 2, 1959.

4. Bushinskiy, G. I., and L. I. Bogolyubova, Konkretsii fosfatizirovannogo boksita iz nizhneyurskogo ugol'nogo plasta v okrestnostyakh g Karpinska na Severnom Urale. [PHOSPHATIZED BAUXITE CONCRETIONS FROM THE LOWER JURASSIC COAL SEAM IN THE VICINITY OF THE CITY OF KARPINSK IN THE NORTHERN URALS]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 1, 1960.

5. Val'ts, I. E., O novoy terminologii elementov iskhodnogo materiala iskopayemykh ugley. [A NEW TERMINOLOGY FOR THE ELEMENTS OF THE SOURCE MATERIAL OF FOSSIL COALS]: Tr. Labor. Geol. Uglya Akad. Nauk SSSR, Vyp. 6, 1956.

6. Ginzburg, A. I., O klassifikatsiyakh i nomenklaturakh mikrokomponentov ugley. [ON THE CLASSIFICATION AND NAMES FOR THE MICROCOMPONENTS OF COALS]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 6, 1958.

7. Gudzhedzhiani, B. I., Vzaimosvyaz' petrograficheskogo sostava tkibul'skikh ugley s ikh obogatimostyu i khimiko-tekhnologicheskimi stvoystvami. [INTERRELATIONSHIP BETWEEN THE PETROGRAPHIC COMPOSITION OF THE TKIBUL' COALS AND THEIR BENEFICIATION AND CHEMICAL AND TECHNOLOGICAL PROPERTIES]: Tr. Labor. Geol. Uglya Akad. Nauk SSSR, Vyp. 6, 1956.

8. Zhemchuzhnikov, Yu. A., Vvedeniye v petrografiyu ugley. [INTRODUCTION TO COAL PETROGRAPHY]: ONTI, 1934.

9. Zhemchuzhnikov, Yu. A., Razvitiye uglenakopleniya v geologicheskoy istorii. [THE DEVELOPMENT OF COAL FORMATION IN GEOLOGIC HISTORY]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 3, 1955.

10. Kalinenko, V. V., Genezis yurskikh ugley Tuvy. v kn. genezis tverdykh goryuchikh iskopayemykh. [THE ORIGIN OF THE JURASSIC COALS OF TUVA. In the book, THE GENESIS OF SOLID FOSSIL FUELS]: Moscow, 1959.

11. Krylova, N. M., I. E. Val'ts, A. A. Lyuber and A. I. Ginzburg, Osnovnyye printsipy veshchestvenno-petrograficheskoy klassifikatsii i terminologii gumusovykh ugley. [FUNDAMENTAL PRINCIPLES OF THE MATERIAL AND PETROGRAPHIC CLASSIFICATION AND TERMINOLOGY OF HUMIC COALS]: Tr. Labor. Geol. Uglya Akad. Nauk SSSR, Vyp. 6, 1956.

12. Rusanova, O. D., Stroyeniye ugol'nogo kompleksa angrenskogo mestorozhdeniya. [THE STRUCTURE OF THE COAL COMPLEX OF THE ANGREN DEPOSIT]: Tashkent, 1959.

13. Rezolyutsiya Vsesoyuznogo soveshchaniya uglepetrografov. [RESOLUTION OF THE ALL-UNION CONFERENCE OF COAL

PETROGRAPHERS]: Izd. Otdel. Tekhn. Nauk Akad. Nauk SSSR, 1956.

14. Tarakanova, Ye. I., Petrograficheskiye tipy ugley i stroyeniye ugol'nykh plastov mestorozhdeniy severnoy chasti Turgayskoy nizmennosti. [PETROGRAPHIC COAL TYPES AND THE STRUCTURE OF THE COAL SEAMS IN THE DEPOSITS OF THE NORTHERN PART OF THE TURGAY LOWLAND]: Tr. Labor. Geol. Uglya Akad. Nauk SSSR, Vyp. 6, 1956.

15. Timofeyev, P. P., K voprosu o svyazi geneticheskikh tipov ugley s obstanovkami osadonakopleniya. [ON THE CONNECTION BETWEEN THE GENETIC TYPES OF COAL AND THE CONDITIONS OF SEDIMENTARY ACCUMULATION]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 5, 1952.

16. Chernousov, Ya. M., Strukturno-geneticheskiye zakonomernosti mesozoyskogo uglenakopleniya na vostochnom sklone Srednego i Severnogo Urala. [STRUCTURAL-GENETIC LAWS GOVERNING THE ACCUMULATION OF MESOZOIC COALS ON THE EASTERN SLOPES OF THE URALS]: Aftoref. Diss. Kand. Geol. -Min. Nauk, 1955.

17. Yablokov, V. S. and L. I. Bogolyubova, Geneticheskiye tipy ugley srednego karbona yugo-zapadnoy chasti Donbassa [GENETIC TYPES OF MIDDLE CARBONIFEROUS COALS IN THE SOUTHWESTERN PART OF THE DONETS BASIN]: Izv. Akad. Nauk SSSR, Seriya Geologicheskaya, No. 6, 1951.

18. Yablokov, V. S., and L. I. Bogolyubova, Geneticheskiye tipy ugley i stroyeniye ugol'nykh plastov. V kn. Stroyeniye i usloviya nakopleniya osnovnykh uglenosnykh svit i ugol'nykh plastov srednego karbona Donetskogo basseyna. [GENETIC TYPES OF COAL AND THE STRUCTURE OF COAL SEAMS. In the book, THE STRUCTURE AND CONDITIONS OF ACCUMULATION OF THE MAIN COAL-BEARING SUITES AND COAL SEAMS OF THE MIDDLE CARBONIFEROUS IN THE DONETS BASIN]: Tr. Geol. In-ta Akad. Nauk SSSR, Vyp. 15, Ch. 1, 1959.

Geological Institue of the
Academy of Sciences, USSR
Moscow

Received October 16, 1959

THE STAGES IN THE DEVELOPMENT OF IGNEOUS ACTIVITY AND ORE FORMATION IN THE MOBILE ZONES OF THE LESSER CAUCASUS[1]

(From the Example of the Nakhichevan Folded Region)

by

SH. A. AZIZBEKOV

The territory of the Nakhichevan folded region of the Lesser Caucasus embraces parts of three first-order structures: the Sharur-Dzhul'fa anticlinorium, the Ordubad synclinorium and the Zangezur anticlinorium. These structures are oriented in the direction of the general trend (NW 290-330°) of the Caucasus, and their formation is associated with pre-Cretaceous (Early Jurassic?) linear folding within the Sharur-Dzhul'fa anticlinorium and the post-Oligocene-pre-Miocene folding in the Ordubad synclinorium and the Zangezur anticlinorium.

The geologic history of these structures reveals three major cycles of development. The first cycle embraces the period from the Jurassic to the Eocene, characterized by predominant uplift in the area of the Sharur-Dzhul'fa anticlinorium and, associated with this, a later displacement of the Ordubad zone of subsidence from west to east. This displacement of the subsidence took place: 1) in the interval between the Triassic and Jurassic, 2) during the Early Cretaceous and 3) in the interval between the Paleocene and the Early Eocene.

Between the Triassic and Jurassic the region underwent uplist (in the Sharur-Dzhul'fa anticlinorium, composed of terrigenous-carbonate deposits dating from Devonian to Triassic); this ended in the Liassic with the initiation of the Negram-Aznabyurt basin (the first, or initial stage of the geocyncline) and the igneous actvity which formed the Early Jurassic extrusive series (diabase and pyroxene porphyrites and their pyroclastic derivatives) and the layered gabbro-diabase and diabase intrusives of the Dzhul'fa area of the Araks and the Eastern Arpa-Chay regions. In the Middle Jurassic were deposited normal marine sediments, beginning with sandstones, followed by clays and marls and ending with the deposition of a regressive series of micaceous sandstones and gravelites in the Late Jurassic.

In the Early Cretateous the region was uplifted, and with the Albian entered into a new phase of geosynclinal development, which lasted throughout the entire Late Cretaceous and Paleocene. As in the Early Jurassic, the initiation of the Cretaceous subsidence was accompanied by volcanic activity (the Albian extrusive series of quartz and quartz-less porphyrites and their pyroclastic differentiates of the Negram-Aznabyurt area), as well as a marine transgression with conglomerates, sandstones and clays of the Cenomanian-Turonian); the regression ended (limestones and sandstones of the Campanian) and the basin was dried up (cyclical sandstone-clay deposits of the Datian stage and the Paleocene).

After the Datian regression, at the boundary between the Paleocene and Early Eocene, one notes a new change (the second, or early, stage of the geosyncline) in the deposition of the zones of uplift and subsidence. The axial zone of the Yerevan-Ordubad geosyncline is displaced eastward, into the area of the western slopes of the Zangezur Range. A transverse uplift was formed during this time in the Western Daralagez, dividing the Yerevan-Ordubad geosyncline into two basins — the Yerevan in the northwest and the Ordubad in the southeast.

The Eocene extrusive igneous activity in the Ordubad basin (3) reached its greatest development in the Early Eocene and became somewhat less intensive in the Middle Eocene. The distribution of facies zones in the Lower Eocene deposits indicates that the main centers of submarine eruptions were located in the axial part of the basin. The occurence in the Azhnavir gorge of a series of porphyrite dikes grading into Early Eocene porphyrite flows of the same composition suggests that, in addition to eruptions of the central type, as indicated by the enormous masses of pyroclastic formations, there were also fissure flows.

The extrusive igneous activity of Middle Eocene time (the period of deposition of

[1]Etapy razvitiya magmatizma i rudoobrazovaniya v podvizhnykh zonakh Malogo Kavkaza (na primere Nakhichevanskoy skladchatoy oblasti).

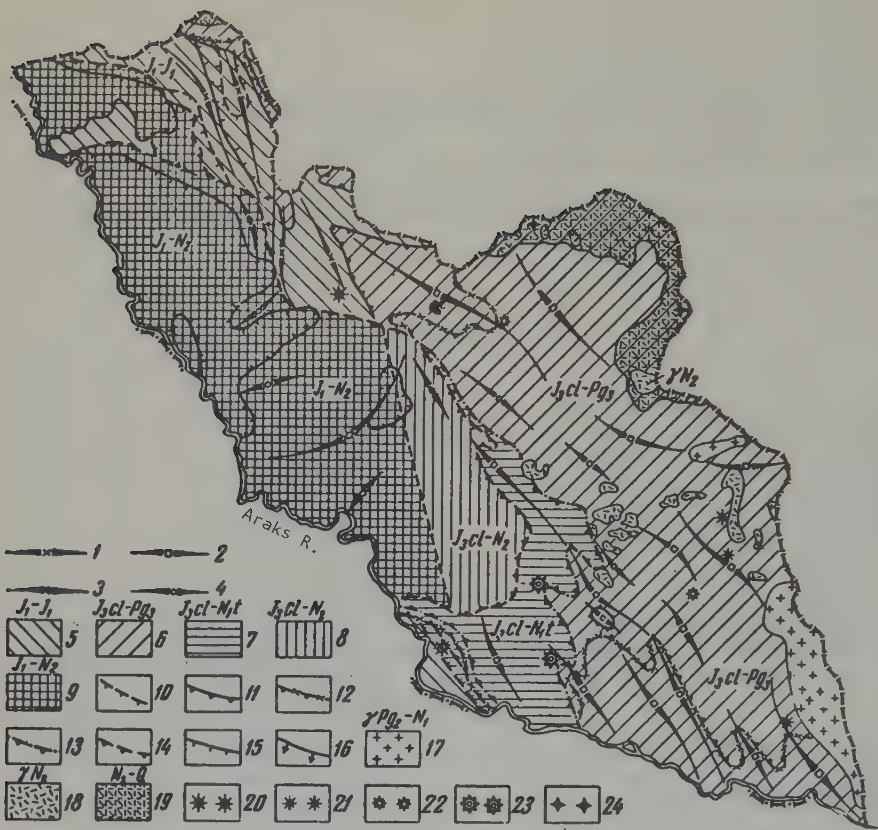

FIGURE 1. Sketch map of the Nakhichevan mobile zone of the Lesser Caucasus.

Anticlines formed before: 1 - Middle Jurassic, 2 - Late Oligoncene, 3 - Late Miocene, 4 - Middle Pliocene. Structures: 5 - pre-Alpine uplifts (beginning and end of uplifts, Early Jurassic), 6 - middle-Alpine structures (beginning and end of uplifts, Callovian-Oligocene), 7 - late-Alpine structures (beginning and end of uplifts, Callovian-Oligocene), 8 - Late Alpine structures (beginning and end of uplifts, Early Jurassic-Pliocene), 9 - Late Alpine structures (beginning and end of uplifts, Callovian-Pliocene). Boundaries of structural stages, at bottom of stage: 10 - Upper Carbonfierous, 11 - Lower Cretaceous, 12 - Paleogene, 13 - Oligocene, 14 - Miocene, 15 - Quaternary deposits. Tectonic faults: 16 - fault zones. Intrusives and effusives: 17 - post-Oligocene--pre-Miocene polyphasic granitoid intrusives, 18 - Lower Pliocene intrusives and extrusives, 19 - Lower Pliocene terrestrial effusives. Centers of volcanic formations: 20 - Lower Jurassic, 21 - Lower Eocene, 22 - Middle Eocene, 23 - Lower and Middle Oligocene, 24 - Lower Pliocene.

volcanogenic-sedimentary series) was somewhat different; the intensive subsidence which had begun in the Early Eocene continued, and the transgression reached its maximum in the Early Lutetian. In the east — in the Zangezur zone — only single islands remained; in the northwest the Yerevan and Ordubad basins, which had been separated in the Datian age and in the Paleocene, were joined into a single geosynclinal basin.

The differences in the nature of the facies zones (reflected in the presence of absence of porphyrite agglomerate lavas and limestones or in the predominance of tuffaceous sandstones, argillites and tuff conglomerates) indicate that the great contrast of these movements of subsidence correspondingly expanded the area of extrusive volcanic activity of intermediate acidity, whereas a decrease in the gradients of vertical displacement favored its gradual extinction. The extrusive igneous activity of this time (Early Lutetian) was concentrated around two centers — the western slopes of the Zangezur Range, between the middle reaches of the Gil'yan-Chay River and the upper reaches of the Nakhichevan-Chay River, and the vicinity of the village of Badamly. In the first, the extrusive activity took the form of sporadic outpourings of lavas and pyroclastic ejections in the inherited geosynclinal zone of intensive Early Eocene volcanic activity; in the second a new

magma chamber was active for a short period of time, associated with the appearance of a system of transverse porphyrite dikes grading into extrusive porphyrite lava flows.

The age of the deposition of the volcanogenic-sedimentary series of the Early Lutetian ended with regression and partial erosion of the deposits. This uplift was of short duration and was not accompanied by folding. The subsidence which began immediately after the regression in this region resulted in an outburst of volcanic activity and a marine transgression (marked by the basalt conglomerates in the bottom of the Upper Lutetian series of tuff conglomerates).

The volcanic activity of the central type during this time was cyclical, the cycles separated by times of relative quiescence. One may clearly distinguish three stages of volcanic activity, each of which begins with tuff conglomerates grading upward into agglomeratic porphyrite lavas, followed again by tuff conglomerates, and ending with tuffaceous sandstones and argillites.

The centers of submarine extrusive activity during the Late Lutetian were located, as in the preceding age, in the central part of the geosyncline, in two areas: the vicinity of the villages of Paraga, Tivi and Alyagi, and along the upper reaches of the Alindzha-Chay River. The local centers of the volcanic activity taking place during the age of the volcanogenic-sedimentary series in the areas of the villages of Badamly and Shadykend, had not yet appeared at this time. Local uplift, created at the beginning of the Middle Eocene during the formation of the tuff conglomerate series, continued to develop in a zone between the villages of Alyagi and Milikh and on the lower reaches of Kyuki-Chay River. This is marked by a change in facies and a decrease in the thickness of the deposits in this zone.

The second cycle of development of the Yerevan-Ordubad geosyncline embraced the period from the Oligocene to the Pliocene and was characterized by a southwestward displacement of the zone of subsidence, associated with the arch-like uplift of the Lesser Caucasus. In this stage one may note two phases, and a twofold change in the plan and nature of the folding: 1) in the interval between the Oligocene and the Miocene and 2) at the end of the Miocene and the beginning of the Pliocene.

The uplift of the area at the end of the Priabonian, caused by the regression in the Ordubad zone of subsidence, was preceded by the beginning of the new epoch in the development of this part of the Lesser Caucasus. Although in the time through the Eocene inclusive the axis of the geosyncline was displaced eastward from one stage of development to the next — that is, there was a predominance of uplift in the Sharur-Dzhul'fa zone — from this time on there was a change: the subsidence began to be displaced successively westward and southwestward. This was apparently the beginning of the inversion of the Yerevan-Ordubad geosyncline and the formation of the Miskhan-Zangezur anticlinorium in its present form.

The deposition of the Lower and Middle Oligocene series was preceded by a certain interruption and a partial erosion of the Upper Eocene deposits. The subsidence (the end of the early stage of the geosyncline) in the Darrydag-Dzhagry zone caused an intensive outburst of volcanic activity in the Ordubad zone, along with the formation of a volcanogenic series. In the Yerevan zone, where the movements were on a considerably smaller scale, the volcanic activity was less violent, and the Oligocene deposits are thus represented mainly by normal marine sediments lying conformably upon the Upper Eocene rocks. The volcanic activity of the Early and Middle Oligocene times was of the central type, and its extrusive-clastic material of intermediate acidity (volcanic conglomerates, breccias, tuffs and breccial andesites) were formed under the conditions of a continental climate and a dry land of low elevation, with fresh-water lakes existing upon it for a short time.

The end of the epoch of deposition of the Lower and Middle Oligocene volcanogenic series coincided with a violent occurrence of tectonic movements (the third, or folded, and batholithic stage of the geosyncline). The uplift of the Zangezur anticlinorium, which began as early as the Late Eocene and continued into the Oligocene, ended with folding and with the intrusion into the axial part of the anticlinorium of the largest batholith in the Lesser Caucasus, the post-Oligocene — pre-Miocene polyphase Megri-Ordubad granitoid batholith (4). The folding embraced the entire Ordubad geosyncline and the zone in which it adjoins the Sharur-Dzhul'fa anticlinorium (5). Ultimately the movements were reflected in the formation of systems of reverse faults and thrusts. This phase of tectonic movements marked the beginning of the formation of superimposed basins (the Paradash, Nakhichevan, Tirkesh and Batabat basins) and uplifts (Mindzhanavad, Agkain and Karaguzey uplifts), all trending west-northwest.

By the end of the Oligocene and beginning of the Miocene, the Ordubad synclinorium was drawn into the uplift of the Lesser Caucasus, and finally terminated its existence as a region of subsidence (the fourth, or late, stage of the geosyncline). The region of subsidence during this time was moved toward the southwest — toward the flank of the Sharur-Dzhul'fa anticlinorium, divided by the Nakhichevan basin into two anticlinoria of lower orders, the Sharur in the northwest and the Dzhul'fa in the southeast. This "superimposed" Nakhichevan basin was bordered on the north and east by a zone of uplift, and in

the south and southwest opened out into Iran (the Urmiyskaya Valley) and into Turkey (the Bikermanovskaya Valley). In the Late Oligocene and Miocene epochs the Nakhichevan basin continued to move westward, and was not joined to the Ararat basin in the northwest until the Late Miocene (in the Late Sarmatian). The Upper Oligocene and Miocene deposits (2) which filled the Nakhichevan basin lie unconformably upon deposits dating from Middle Devonian to Lower and Middle Oligocene.

There is considerably evidence for the supposition that the origin of the Nakhichevan basin was associated with movements along a deep fault, which followed the northern border of the basin. This is indicated both by the extremely high thickness gradients of the Upper Oligocene-Miocene deposits, and by the connection between the folding of the Nakhichevan basin and the Agkain uplift.

In the initial stage of formation of this basin, in the Late Oligocene — Early Miocene, carbonate-terrigenous sediments were accumulated and there were violent local explosions of volcanic activity of intermediate acidity in the two marginal zones of greatest subsidence of the basin's bottom; in the northeastern part of the basin (the Kashirdag-Khachaparakh zone) and the northwestern part (the Ul'ya-Norashen-Sadarak zone). The sinking of the bottom of the basin continued along the inherited pattern, with the deposition of sandy-clay material of the Tarkhan-Chokrak, Karaganda (containing the Negrama salt beds) and Konkskiy strata. In the concluding stage the subsidence spread into the central and western parts of the basin, with the formation of cyclical gypsum-salt-sand-clay deposits of the Lower, Middle (containing the Duzday rock-salt beds and Upper Sarmatian. Finally, the post-Alpine orogenesis at the end of the Miocene and beginning of the Pliocene (Meotisian-Pontian) ended the Nakhichevan basin and terminated the folding trending northeastward in the central part of the basin and northwestward along its periphery (the latter being parallel to the edges of the basin and morphologically closely tied in with the folding of the Ordubad synclinorium). This phase saw the end of the formation of the uplifts trending west-northwest, dividing the Ordubad synclinorium into a number of basins arranged en échelon.

The third cycle of development encompassed the period from the Early Pliocene to the Anthropogene inclusive (the fifth and final stage of the geosyncline). During this time the tectonic movements produced new uplifts, and the Lesser Caucasus entered fully into its continental phase of development. The paroxysm of tectonic movements caused the formation of the last member of the Tertiary system within this territory — the Pliocene Bichenag continental extrusive series. The latter was formed as a result of terrestrial volcanic activity of the central type, in which volcanic explosions played a prominent part in the initial stage, reflected in the formation of andesite and andesite-basalt pyroclastic rocks, with a smaller amount of andesite and andesite-basalt lava outpourings; in the intermediate stage the andesitic lavas were formed in the greatest amount, and in the final stage there was an ejection of pyroclastic matter and outpourings of lavas of differentiated composition ranging from andesite to olivine basalts.

The similarity of the chemical and mineralogical compositions of the extrusive series and the hypabyssal intrusives, as well as the presence of subvolcanic (Dzhindag, Kyzyl-Kaya, Goturdag) transitions from extrusives to intrusives suggest strongly that the igneous activity during the Pliocene took various forms — explosions, effusions, extrusive and intrusive activity.

The Pliocene also saw the beginning of the development of gently sloping discontinuous brachyanticlinal folds trending northwest (330 - 340°) (Buzgov — Darrydag, Badamly-Norashen, Dasta-Remesha, Vanad-Bashkend and Zernel'-Ordubad), which can be traced in the Eocene, Oligocene, Miocene and Pliocene deposits of the Ordubad synclinorium. Their arrangement was undoubtedly inherited from the Eocene-Oligocene structural stage, but in general it forresponds to the trend of the main anticlinorial structures of the first order.

In the Quaternary period, the tectonic movements were manifested in the further growth of discontinuous folds and in the uplift of the northeastern part of the territory, associated with an arch-like uplift of the Lesser Caucasus.

Thus it may be supposed that volcanic activity and tectogenisis are interrelated and occur together, from the example of the complex folded zone of the Ordubad synclinorium (the eastern part of the Nakhichevan Republic), formed as a result of three tectonic-igneous cycles — an Early Alpine (Jurassic), a Middle Alpine (Cretaceous-Paleogene) and a Late Alpine (Neogene-Anthropogene). These cycles encompass five stages of volcanic activity, Early Jurassic, Albian, Early and Middle Eocene, Early and Middle Oligocene and Miocene-Pliocene, corresponding to the five stages in Yu. A. Bilibin's scheme, which, however, in this case applies not to any particular single tectonic-igneous epoch, but to the entire history of development of the mobile zone from the moment of its initiation to its transformation into a young platform. The first (first two stages) and second (end of the early stage) cycles characterize the geosynclinal period of development of the mobile zone, the third (batholithic) stage of the second cycle marks its transformation into a folded zone with the injection of a large polyphase granitoid batholith and, finally, the third cycle (the last two stages) corresponds to its further

development toward becoming a platform with post-folding extrusives and "minor" hypabyssal andesite-dacite and dacite intrusives and extrusives. The formation of the latter is associated with the growth of discontinuous folds, whereas the intrusion of the batholith is due to the uplift of the Zangezur anticlinorium.

The spatial disposition of the intrusive complexes of this mobile zone indicates that they are associated with deep (or marginal) faults, which border the various tectonic zones (between the Zangezur anticlinorium and the Ordubad synclinorium and the Megri-Ordubad batholith, between the Ordubad synclinorium and Nakhichevan superimposed basin and the extrusive complex of the Karadzhalal-Khalkhal Ridge), each of which has its own stratigraphic section (with different facies, thicknesses and stratigraphic completeness) and is characterized by tectonic movements of different ages, tectonic structures of different morphologies, and by its own specific features of igneous activity and ore formation.

The post-Oligocene — pre-Miocene Megri-Ordubad polyphase granitoid batholith contains hydrothermal molybdenum and copper-molybdenum mineralization (including the Paragachay deposit) located in the endocontact zone (in shear fractures) of a granosyenite intrusive of the batholith extending from Nyusnyusa-Gekgyundura, in the southeast, to Kyzgyalin-Chukhura, in the northwest. In the molybdenum type of ore mineralization the molybdenite, with a small admixture of pyrite and chalcopyrite, occurs either in quartz veins or, more rarely, in contact zones between faults; in the copper-molybdenum type of ore mineralization the chalcopyrite and molybdenite are encountered as small dispersions and veinlets in the marginal facies of the granosyenite intrusives (gabbro-diorites, diorites and quartz-diorites) and more rarely as independent quartz copper-molybdenum veins.

The injection of the Lower Pliocene hypabyssal "minor" andesite-dacite and dacite intrusives, separated from the intrusion of the Megri-Ordubad batholith by a stage of development of a system of superimposed basins and uplifts of Miocene and Lower Pliocene age,[2] was acccompanied by the formation of lead-zinc, antimony-arsenic and manganese deposits and ore occurrences. The lead-zinc ores may be divided into polymetallic (Agdara, Nasirvaz) and pure lead-zinc (Gyumushlug) ores. The first are characterized by a constant association of galena and sphalerite with lesser amounts of chalcopyrite, pyrite, fahlerz, gold and silver; the second are represented either by galena-sphalerite or only galena mineralization, with an admixture of silver. The ore-controlling factors in these two types of deposits are pre-ore faults of northwestward or almost equatorial trends (Gyumushlug), domical structures of anticlinal folds (Agdara) and the lithologic composition of the surrounding rocks, which are Middle Devonian limestones (Gyumushlug), and the junction between rocks of different compositions (porphyrites and tuffaceous sandstones) of Middle Eocene age (Agdara).

The antimony-arsenic deposits and ore occurrences are represented by three groups: 1) realgar-orpiment (Darrydág deposit), 2) realgar-antimonite (Sal'varta deposit) and 3) antimonite (in the vicinity of the Darrydag realgar-orpiment deposit) mineralizations. Finally, the manganese mineralization is associated with a Lower Pliocene extrusive series in the area of the Bichinag swell.

Thus the formation of the post-Oligocene and pre-Miocene molybdenum-bearing Megri-Ordubad granitoid batholith corresponds in time to the rearrangement of the zones of uplift and subsidence — to the superimposition of the Araks Miocene basin and the uplift of the Zangezur anticlinorium, with which the batholith is morphologically and genetically associated. The formation of the Lower Pliocene hypabyssal "minor" andesite-dacite and dacite intrusives, which contain lead-zinc, arsenic-antimony and manganese mineralization, is connected with the formation of structures of lower orders (discontinuous folds with meridional and northwestward trends) within the Ordubad synclinorium and, to a lesser degree, the Zangezur anticlinorium. Moreover the steep flanks of the brachyanticlines and the periclinal plunges of the discontinuous folds contain minor intrusives with intersecting contacts, whereas in the adjacent basins there are conformable intrusives separated from the chief marsifs. In addition, with the injection of Megri-Ordubad batholith was accompanied by processes of assimilation and contamination, as well as contact and hydrothermal metasomatism, resulting in the formation of skarns, epidosites, secondary quartzites (in places containing andalusite) and hornfelses in the aureole. The injection of the "minor" hypabyssal intrusives was accompanied by mechanical, and not chemical, alteration of the surrounding rocks.

These differences in the formation of the metalliferous intrusives of various ages suggest the proper directions in which to orient prospecting and exploration for the discovery of new deposits of economic minerals.

REFERENCES

1. Azizbekov, Sh. A., Osnovnyye cherty geologicheskogo stroyeniya Nakhichevanskoy

[2]The age of these depressions and upwarps is established by the fact that their structure contains Upper Oligocene and Miocene deposits, whereas the Lower Pliocene Bichenag effusive strate cover the leveled, eroded folds of this system.

ASSR. [MAIN FEATURES OF THE GEOLOGIC STRUCTURE OF THE NAKHICHEVAN ASSR]: Izv. Akad. Nauk AzerSSR, no. 5, 1949 (Supplement).

2. Azizbekov, Sh. A., O vozraste solenosnoy tolshchi Nakhichevanskoy mul'dy. (Azerbaydzhanskaya SSR). [ON THE AGE OF THE SALINIFEROUS STRATA IN THE NAKHICHEVAN TROUGH (AZERBAYDZHAN SSR)]: Dokl. Akad. Nauk SSSR, t. 45, no. 5, 1952.

3. Azizbekov, Sh. A., Tretichnyye effuzivy Nakhichevanskoy ASSR. V kn., Geologiya Azerbaydzhana. Petrografiya. [THE TERTIARY EFFUSIVES OF THE NAKHICHEVAN ASSR. In the book, THE GEOLOGY OF AZERBAYDZHAN. PETROGRAPHY]: Izd-vo Akad. Nauk AzerbSSR, 1952.

4. Azizbekov, Sh. A., Konguro-Alangezskaya polifaznaya intruziya (yugo-zapadnaya chast'). V kn., Geologiya Azerbaydzhana. Petrografiya. [THE KONGUR-ALANGEZ POLYPHASIC INTRUSIVE (SOUTHWESTERN PART). In the book, THE GEOLOGY OF AZERBAYDZHAN. PETROGRAPHY]: Izd-vo Akad. Nauk AzerbSSR, 1952.

5. Azizbedkov, Sh. A., and G. P. Kornev, Tektonika Nakhichevanskoy ASSR po novym dannym. Tr. Soveshch. po tektonike al'piyskoy geosinklin. obl. Yuga SSSR. [THE TECTONICS OF THE NAKHICHEVAN ASSR IN THE LIGHT OF NEW DATA. PUBLICATIONS OF THE CONFERENCE ON THE TECTONICS OF THE ALPINE GEOSYNCLINAL REGION IN THE SOUTHERN USSR]: Baku, 1956.

6. Leont'yev, L. N., Tektonicheskoye stroyeniye i istoriya geotektonicheskoo razvitiya Malogo Kavkaza. [THE TECTONIC STRUCTURE AND GEOTECTONIC HISTORY OF THE LESSER CAUCASUS]: Byull. Mosk. o-va ispyt. prirody, nov. ser., t. 54, otd. geol., t. 24, vyp. 4, 1949.

7. Paffengol'ts, K. N., Tretichnyye neointruzii vostochnogo Zakavkaz'ya. V kn., Geologiya SSSR. [THE TERTIARY NEOINTRUSIVES OF THE EASTERN TRANSCAUCASUS. In the book, THE GEOLOGY OF THE USSR]: T. 10, ch. 1, Gosgeolizdat, 1941.

8. Khain, V. Ye., Tektonicheskoye stroyeniye Azerbaydzhana. V kn., Tr. Konf. po vopr. region. geol. Zakavkaz'ya (noyabr' 1951). [THE TECTONIC STRUCTURE OF AZERBAYDZHAN. In the book, PUBLICATIONS OF THE CONFERENCE ON THE REGIONAL GEOLOGY OF THE TRANSCAUCASUS (NOVEMBER 1951)]: Izd-vo Akad. Nauk AzerbSSR, 1952.

Institute of Geology of the Azerbaydzhan SSSR, Baku

Received May 5, 1959

THE EFFECT OF PROCESSES OF ASSIMILATION ON THE DISTRIBUTION OF ACCESSORY MINERALS IN GRANITOIDS[1]

by

V. V. LYAKHOVICH AND A. D. CHERVINSKAYA

PRELIMINARY REMARKS

A study of the manner in which the distribution and composition of accessory minerals is affected by processes of assimilation occurring in the formation of granite massifs is an extremely important part of geology. On the one hand, this will provide a basis for reliably distinguishing specific accessory minerals whose formation is due to assimilation of the surrounding rocks, thus providing additional mineralogical criteria by which to judge the processes of contamination or hybridization occurring during this formation; on the other hand, the very nature of the various species of accessory minerals occurring during the assimilation will provide a basis for a better judgment of the composition of the material assimilated by the magma.

The change in the content of accessory ore minerals in contaminated granitoids may provide proofs of the enrichment of granitic magmas by metallic elements under the influence of assimilation. Finally, as has been pointed out repeatedly by K. A. Vlasov [6], assimilation processes may be an important factor in the concentration or dissemination of particular rare elements and, consequently, may favor or hinder the formation of deposits of such elements.

To study the effect of assimilation of the surrounding rocks on the composition and content of the accessory minerals, we have selected and thoroughly studied a number of samples from pure and contaminated granitoids of Western Tuva, the Middle Urals and the Northern Caucasus. For comparison, we have also cited data obtained earlier on the granitoids of the Gornyy Altay.

The samples were treated as follows. A sample weighing 10 kg, broken down to fragments of -0.5 mm in size in jaw and roller crushers, was washed twice in a KTs-30 concentration table. The resulting concentrate was broken down into fractions of +0.25 and -0.25 mm, from which the magnetite was removed. After the magnetic separation, the fractions were placed in large beakers with bromoform. The concentrate was then passed over an electromagnet, after which the medium-magnetic and non-magnetic fractions were ground in mortars. By this means it was possible to make a more complete separation of minerals with similar electromagnetic properties (for example, biotite from orthite and tantaloniobates, and zircon from apatite). Each weighed fraction was studied mineralogically, and then divided into four parts for quantitative mineral determinations in one of the four parts.

The quantitative content of the mineral in the fraction was calculated by weight for the entire concentrate, and then for the rock as a whole. When the final content in grams per metric ton had been obtained, this result was multiplied by a correction coefficient selected ampirically and designed to compensate for the loss during the crushing and washing of the sample. Nevertheless if one translates percent per volume into percent per weight without taking into account the specific weight of each mineral, when a correction coefficient is introduced for the weight of the concentrate as a whole and not for each mineral separately, an error will naturally result. In view of the uniformity of the methods used, however, all the figures cited below are quite comparable and fully reflect the nature of the changes in the amount of accessory minerals. Table 3 below shows considerable discrepancies in the figures, since the methods used by us have specific limits of accuracy. When the mineral contents are large, discrepancies of some 30 to 50 grams per metric ton are quite permissible. As regards the rare minerals, their presence or absence even as isolated grains can be determined quite accurately by examining the entire fraction, and not merely that portion in which the grains were counted. In identifying the minerals we have made extensive use of optical and microchemical methods, as well as spectrum and structural X-ray analysis.

---

[1] O vliyanii protsessov assimilyatsii na rasprostraneniye aktsessornykh mineralov v granitoidakh.

CHARACTERISTIC INDICATIONS OF HYBRID OR CONTAMINATED ROCKS

In the injection and emplacement of a granitic magma in the upper layers of the earth's crust there is frequently an assimilation of the surrounding rocks, represented usually by sedimentary (contamination; H. Read, 1923), and more rarely by igneous (hybridism; A. Harker, 1905) formations. Such assimilation naturally leads to changes in the composition of the original granitic magma and, depending on the extent of the assimilation, the newly formed rocks may show a great variety.

In a number of cases, however, the processes of assimilation can be judged only on the basis of the texture, structure of mineral composition of the granitoids. External indications of assimilation of foreign matter are found in the presence of xenoliths and spotty taxitic textures caused by an alternation of parts of the rock enriched to varying degrees in dark-colored minerals. The structure of granitoids frequently shows poikilitic, and especially cribriform and antiperthitic growths in the plagioclases. Traces of assimilation are frequently also to be found in a very high content of dark-colored minerals, together with the presence of antagonistic minerals (olivine-quartz, felspathoids-quartz), and, finally, in the simultaneous presence of several members of the reaction series with signs of resorption of the end members (pyroxene-amphibole-biotite, with the pyroxene in a state of decomposition). These may be considered the most general and common features [8, 14, 16].

Another peculiarity of hybrid or contaminated rocks is their enrichment in accessory minerals, especially apatite, sphene or magnetite, as observed by a number of investigators [11, 12, 18, 20, 25]. As an example, we may cite the granites of the Chatkal Range, in which the amount of accessory minerals in the zone of contact with a gabbro increases from 0.6 to 2.6% by volume [7], or the granodiorites of the Kokpatass intrusive, in which the content of accessory minerals in the contact, contaminated parts increases from 0.3 to 1.77% by volume [2]. In hybrid granites of the Osnitskiy complex (Volyn'ya), as compared to normal granites, the amount of magnetite increases from 0.45 to 0.86% by weight, the amount of sphene from 0.06 to 0.62% by weight, and the amount of apatite from 0.05 to 0.45% by weight [21].

According to the data in the literature, sphene, apatite and magnetite predominate in hybrid or contaminated rocks. Increased amounts of these minerals have been constantly noted in the contaminated granitoids of the Karamazar [5], Central Transbaykal [9], Central Kazakhstan [24], the Terskey-Alatau [17], Volyn'ya [23], the hybridized granodiorites of the Kuznetskiy Alatau [8], the Eastern Transbaykal [30], the Uman Pluton (in the Ukraine; [32]) and in the Zhitomir-Kirovograd granites [18].

The literature contains very frequent mention that a characteristic feature of contaminated granitoids is the presence of andalusite, staurolite, sillimanite and cordierite, resulting from the contamination of the granitic magma by shales or sandy-argillaceous rocks. The presence of these minerals has been noted in the contaminated granitoids of Western Uzbekistan [1], the Karamazar [5], Chukotka [19], the Soviet Far East [29], the Ukraine [32], and in the young granites of Colorado [35] and Dartmoor [36]. I. Kh. Khamrabayev [28] also observes that the amount of sillimanite in the outermost facies of the Susingen granitoids, at the contact between these and hornfels rocks, reaches 8%. Much more rarely one encounters mention of the fact that hybrid or contaminated rocks contain increased amounts of epidote [17], ilmenite or sulfides [32], spinel [9, 37] and garnet [4, 5, 19].

Hybrid rocks are usually enriched in orthite. For example, in Western Uzbekistan the orthite is concentrated in older granitoids, which bear clear traces of assimilation [29]. The contact zones of the granites in Colorado contain more orthite than the central parts of these massifs [37]; finally, in the granites of Victoria (Australia) orthite is particularly frequent in those granites in which the presence of basic xenoliths indicates that the granite has been contaminated by foreign materials [36].

A BRIEF PETROGRAPHIC DESCRIPTION OF THE GRANITOIDS INVESTIGATED

Contaminated varieties of granitoids are also distinguished visually from unaltered varieties by their abundance of dark-colored minerals, xenoliths and their predominant occurrence in the contact zones or crests of the massifs.

The Tongul' massif, in Western Tuva, is composed of porphyritic medium-grained granites, frequently with a gneissic texture. These granites are characterized by intensive pelitization and perthitization of the potassium felspar, and by frequent chloritization of the biotite along with relatively fresh plagioclase (No. 15-20), sometimes altered to sericite, along fractures. These granites penetrate and metamorphose Middle Cambrian (schists, quartzites) and Lower Silurian (chlorite-sericite schists) deposits and frequently contain numerous xenoliths of these rocks altered to hornfels; the composition of the granite itself also changes; hornblende appears, and the amounts of biotite and plagioclase increase.

The Edygey massif occurs among Silurian shales which contain interlayers of limestones,

Table 1

Comparison of the Chemical Compositions of Normal and Hybrid (Contaminated) Granites (in %)

Oxides	Middle Urals[1] (Shilovo-Konev massif)		Western Tuva (Tongul' massif)		Northern Caucasus[2] (El'dzhurta massif)			Gornyy Altay (Talitskiy massif)	
	normal granite, sp. 386	hybrid granite, sp. 391	normal granite, sp. 165	hybrid rock, sp. 166	granite from center of massif	granite from contact area with hornfels	granite from contact area with limestones	normal granite	hybrid rock
SiO_2	69.63	53.54	76.36	62.91	71.26	64.48	60.72	75.00	67.66
TiO_2	0.52	1.42	0.01	0.15	0.42	1.11	Trace	0.10	0.73
Al_2O_3	16.03	17.82	12.76	15.04	14.90	15.67	23.74	14.53	13.95
Fe_2O_3	1.04	3.33	0.64	3.68	0.68	1.59	0.48	0.73	3.68
FeO	1.04	4.82	0.58	4.68	1.50	3.97	0.56	0.62	2.40
MnO	0.04	0.17	0.02	0.08	0.02	0.09	0.08	0.04	0.09
MgO	1.08	2.53	0.24	2.14	0.75	1.90	0.68	0.03	1.10
CaO	1.90	4.04	0.57	4.31	1.81	2.65	7.45	1.0	4.0
Na_2O	4.02	5.45	3.19	3.14	3.28	3.43	4.79	3.20	3.00
K_2O	4.23	4.37	4.89	3.41	4.37	3.96	1.20	4.50	2.84
H_2O^-	—	—	0.10	0.10	0.07	0.97	—	—	—
H_2O^+	—	—	0.42	0.61	—	—	0.08	—	—
P_2O_5	0.11	1.53							
S	0.02	0.37							
Ignition losses	0.79	0.89	—	—	0.80	—	0.24	0.40	0.62
Total	100.45	100.28	99.78	100.25	99.86	99.82	100.02	100.15	100.07
			Analysis by T.A. Kapitonova (IMGRE)					Analysis by A.V. Bykova (IMGRE)	

[1]Analyses taken from B.M. Kupletskiy's paper, "Granite Intrusives on the Eastern Slopes of the Middle Urals and their Rare-metal Ore Mineralization", Tr. Instituta Geologicheskikh Nauk Akad. Nauk S.S.S.R., vyp. 83, Petrogr. Ser., no. 26, 1947.

[2]Analyses taken from V.V. Lyakhovich's paper, "The endomorphic alteration of the young Baksan granites at their contact with limestones", Tr. Instituta Geologicheskikh Nauk Akad. Nauk S.S.S.R., vyp. 148, Geol. Ser., no. 44, 1953.

Table 2

Quantitative Mineral Compositions of Normal and Hybrid (Contaminated) Granitoids (in %)

Minerals	Middle Urals[1]				Western Tuva[2]				Northern Caucasus[3]			Gornyy Altay[4]	
	Chelyabinsk massif		Shilovo-Konev massif		Tongul' massif		Edygey massif		El'dzhurta massif			Talitskiy massif	
	normal granite, sp. 441	hybrid rock, sp. 443	normal granite, sp. 386	hybrid rock, sp. 391	normal granite, sp. 165	hybrid rock, sp. 166	normal granite, sp. 207	hybrid rock, sp. 209	normal granite	granite from contact area with hornfels	granite from contact area with limestones[5]	normal granite	hybrid rock
Pyroxene	—	—	—	—	—	—	—	9.79	—	—	—	—	—
Hornblende	—	3.15	—	—		18.10	8.43	15.00	—	—	—	—	5.62
Biotite	5.05	21.25	4.15	15.35	3.32				7.84	24.77	4.1	4.56	13.76
Plagioclase	10.70	26.35	37.25	39.35	18.40	29.20	45.89	53.98	31.56	13.40	48.30	22.02	30.70
Potassium felspar	44.55	28.15	30.10	30.35	39.74	30.82	9.89	5.24	34.53	34.60	20.13	35.58	16.44
Quartz	38.10	19.05	27.20	13.95	33.95	18.40	27.71	9.76	25.70	25.96	25.32	33.98	27.37
Secondary minerals	1.6	2.05	1.30	1.00	3.81	2.39	6.73	1.27	—	—	—	2.89	3.35
Accessory minerals	—	—	—	—	0.78	1.09	1.35	4.97	0.37	1.27	2.15	1.97	2.76
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Each column is an average of two determinations

[2]Each column is an average of five determinations

[3]Each column is an average of eight determinations

[4]Each column is an average of twenty determinations

[5]There is sometimes a small discrepancy between the data from the chemical analyses and those of the quantitative mineral-content determinations. This is due to the fact that quantitative mineral-content determinations are usually averaged from several thin sections, each of which characterizes some variety of contact granitoids of variable composition.

and is distinguished by its heterogeneous structure. Its central part is composed of pinkish-gray, medium-grained granodiorite, whose minerals are intensively altered: the biotite is chloritized, the plagioclase is sericitized and altered to carbonate, and the potassium felspar is somewhat pelitized. Near the periphery, at the contact with the gabbro which surrounds this massif in a narrow zone, these granodiorites are gradually replaced by dark hybridized rocks consisting chiefly of plagioclase. They also contain monoclinic pyroxene with hornblende and biotite developing after the pyroxene.

In the Shilovo-Konev massif, Middle Urals, the rocks surrounding the massif are sedimentary (shales, limestones) and extrusive (albitophyres) of Devonian and Carboniferous age. The massif is composed of medium-grained microcline granites, distinguished by the minerals composing it, although along with biotite it sometimes also contains large books of muscovite. In some cases the granites are literally overfilled with inclusions of large and small amphibolite xenoliths, and thus become melanocratic. They contain increased amounts of plagioclase and biotite, which is pleochroic in shades of greenish and brown.

The Chelyabinsk massif occurs chiefly among Silurian sedimentary (phyllite) and Middle Devonian extrusive (porphyrite) rocks. The medium-grained biotite porphyritic granites which compose this massif sometimes contain a considerable amount of xenoliths of quartz diorite composition, belonging to an earlier intrusive phase. These hybrid granitoids consist primarily of segregations of fresh plagioclase (No. 25-30) and hornblende replaced by biotite.

The Talitskiy massif, in the Gornyy Altay, is composed of biotite porphyritic granites occurring among Lower Silurian sandstones and shales. The minerals that form the granite (biotite, plagioclase No. 18-25 and microcline without a lattice structure) are altered to one degree or another, and such secondary minerals as epidote, zoisite, sericite, and chlorite are present in almost every thin section. The more melanocratic varieties of the granites, developed in the contact zones or the crests of the massif, are characterized by a predominance of plagioclase (No. 30-35) over microcline, by increased contents of hornblende and biotite, and by the constant presence of a large number of xenoliths.

The El'dzhurta massif, in the Northern Caucasus, is composed of fresh biotite porphyritic granites, occurring chiefly among Upper Paleozoic sandstones and shales that have been altered to hornfels. Extensive alterations in the granite are not observed at the contact with the hornfels, but it contains many xenoliths and and is rich in biotite. Such areas in the granite are characterized by an abundance of cribriform structures, in which small rounded grains of quartz penetrate all the other minerals. At the contact between the granites and the limestones there are gray fine-grained granitoids characterized by an abundance of zonal crystals of plagioclase (No. 28-30) and by the presence of diopside crystals replaced by hornblende, which in turn is replaced by biotite.

The changes in the chemical or quantitative mineral composition of the granitoids, which is caused by assimilation of the surrounding rocks, may be seen from the figures in Tables 1 and 2. The most important aspect of the data shown in these tables is the three or four-fold increase in hybrid (contaminated) varieties of the granitoids of such oxides as TiO_2, FeO and Fe_2O_3, and CaO, resulting in corresponding changes in the mineral composition: increase in the amount of calcium-containing (plagioclase, hornblende) and iron-magnesium (hornblende, biotite) minerals. The final result is thus the formation of rocks such as biotite or biotite-hornblende granodiorites, quartz diorites or even diorites.

FEATURES OF THE COMPOSITION OF THE ACCESSORY MINERALS OF NORMAL, HYBRID AND CONTAMINATED GRANITOIDS

The peculiarities of the chemical composition of altered granitoids are even more clearly and obviously reflected in the composition of the accessory minerals. One may easily distinguish minerals whose quantitative content is directly related to the degree of assimilation, and the melting of foreign matter into the magma. The existence of such a direct relationship may serve as a criterion of the magmatic genesis of these minerals, the most important of which are apatite, zircon, orthite, epidote, ilmenite, sphene, magnetite and pyrite; the contents of these minerals exceed their original amounts in unaltered granitoids by tens and sometimes hundreds of times. On the other hand, such minerals as rare-earth phosphates, monazite and xenotime almost disappear in hybrid rocks.

An examination of the contents of accessory minerals given in Table 3 will readily show that the hybrid or contaminated granitoids have highly increased contents of mainly calcium-containing minerals such as apatite, orthite, epidote and sphene. It is therefore quite natural that the abundance of such minerals as are separated out in the magmatic or post-magmatic stages would facilitate the dispersion of elements of the rare-earth group, which would then enter into the lattices of these minerals as isomorphic admixtures, and that true rare-earth minerals would not be formed.

The great enrichment of the hybrid (contaminated) rocks not only in calcium, but also in

Table 3

Changes in the Contents of Accessory Minerals in Normal and Hybrid (Contaminated) Varieties of Granitoids (g/t)

Minerals	Middle Urals				Western Tuva				Gornyy Altay		Northern Caucasus						
	Chelyabinsk massif		Shilovo-Konev massif		Tongul' massif		Edygey massif		Talitskiy massif		El'dzhurta massif						
	Granite	Hybrid granite	Granite	Hybrid granite	Granite	Hybrid granite	Granite	Hybrid granite	Granite	Hybrid granite	Granite	Granite from contact area with limestones		Granite apophyses in limestones	Granite from contact area with hornfels		Granite apophyses in hornfels
	sp. 441	sp. 443	sp. 386	sp. 391	sp. 165	sp. 166	sp. 207	sp. 209	average of 12 samples	average of 6 samples	sp. 524	sp. 527	sp. 567	sp. 532	sp. 545	sp. 560	sp. 556
Apatite	98.1	5827.7	388.8	3890.1	2.0	71.3	20.4	1055.4	243.7	73.7	229.2	84.2	104.0	99.8	191.9	105.0	487.2
Monazite	305.4	Isolated grains	Isolated grains	—	1.3	Isolated grains	0.6	Isolated grains	109.5	—	1.3	1.1	Isolated grains	Isolated grains	55.0	78.3	12.8
Xenotime	1.9	—	3.9	—	2.5	—	Isolated grains	—	7.5	—	—	0.1	—	—	0.6	—	—
Zircon	10.9	497.3	7.8	292.2	145.6	235.3	55.1	437.4	132.0	197.8	195.2	80.6	184.1	116.4	183.2	30.9	224.1
Tantaloniobate	0.3	—	Isolated grains	—	—	—	—	Isolated grains	—	—	—	—	—	—	—	—	—
Uraninite	10.8	Isolated grains	—	—	—	—	—	—	—	—	Isolated	Isolated grains	Isolated grains	Isolated grains	0.8		0.8
Orthite	7.1	71.9	—	Isolated grains	6.7	3.0	3.7	—	24.9	126.1	126.1	215.2	130.1	108.2	39.4	0.1	0.3
Epidote	Isolated grains	2358.8	0.3	67.1	675.4	35.6	322.2	0,1	1929.6	2257.5	0.1	624.5	720.6	0.2	0.1	—	Isolated grains
Tourmaline	»	Isolated grains	Isolated grains	—	Isolated grains	Isolated grains	3.0	Isolated grains	28.5	0.1	Isolated grains	—	Isolated grains	—	Isolated grains	—	—
Garnet	2.1	0.2	0.9	Isolated grains	»	"	0.7	»	21.8	9.7	»	10.3	3100.8	0.7	34.6	Isolated grains	0.1
Vesuvianite	—	—	—	—	—	—	—	—	—	—	—	—	96.8	—	0.8	»	—
Fluorite	9.0	Isolated grains	Isolated grains	0.1	198.2	Isolated grains	Isolated grains	Isolated grains	2.5	1.0	0.2	3.2	—	4.4	0.1	—	Isolated grains
Andalusite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.4	Isolated grains	51.6
Staurolite	—	—	—	—	—	—	Isolated grains	—	—	—	—	Isolated grains	—	—	—	—	—
Ilmenite	926.5	123.9	521.8	2.1	56.0	2301.2	144.1	8869,1	79.5	624.3	24.2	65.7	275.8	3.5	0.8	15.3	23.6
Sphene	0.2	26767.2	127.2	13871.9	1.0	1594.1	98.8	Isolated grains	74.9	224,5	Isolated grains	38.5	1425.0	563.5	Isolated grains	Isolated grains	Isolated grains

Leucoxene	—	Isolated grains	—	—	Isolated grains	Isolated grains	17.8	Isolated grains	—	—	—	—	—	—	8.6	—	—
Rutile	Isolated grains	—	0.4		0.6	—	Isolated grains	»	1.4	—	Isolated grains	0.2	124.5	16.2	0.1	Iso-lated grains	Isolated grains
Anatase	—	—	—	—	3.4	—	0.1	—	—	—	0.1	1.5	—	—	4.8	41.3	3.1
Magnetite	3207.4	22223.6	3344.7	14929.4	2859,9	5288.8	9.4	4184.4	1366.4	10306.5	6.3	Iso-lated grains	—	Isolated grains	0.4	0.1	—
Hematite	Isolated grains	Isolated grains	—	394.1	1471.1	—	235.9	166.7	0.5	—	Isolated grains	—	—	—	—	—	—
Cassiterite	—	—	—	--	Isolated grains	—	—	Isolated grains	—	—	Isolated grains	—	—	Isolated grains	—	—	—
Wolframite	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scheelite	Isolated grains	—	—	—	—	—	8.8	0.1	—	—	—	—	94.3	1.5	0.1	0.1	—
Corundum	90.1	—	0.4	—	Isolated grains	—	—	—	—	—	Isolated grains	Iso-lated grains	Isolated grains	—	—	Iso-lated grains	Isolated grains
Pyrite	90.7	725.9	48.5		0.3	173.9	0.1	Isolated grains	4.0	14.7	0.1	50.3	»	Isolated grains	0.1	»	—
Limonite	2.3	3.1	331.2	15.0	28.0	Isolated grains	172.8	0.3	22.5	125.7	1.7	0.1	»	—	60.6	1.5	0.1
Arsenopyrite	—	—	—	—	—	—	—	Isolated grains	—	—	1.2	—	1.4	2.5	0.8	Iso-lated grains	0.4
Chalcopyrite	—	—	—	—	Isolated grains	—	—	»	—	1.2	0.1	1.0	Isolated grains	Isolated grains	0.4	0.1	Isolated grains
Sphalerite	Isolated grains	—	0.1	—	—	Isolated grains	Isolated grains	»	0.1	-	—	0.8	—	—	—	—	—
Galena	—	—	Isolated grains	—	0.1	»	—	—	—	—	Isolated grains	0.5	—	—	Isolated grains	Iso-lated grains	—
Molybdenite	0.1	Isolated grains	»		1.3	»	Isolated grains	Isolated grains	Isolated grains	0.1	»	1.6	0.1	0.2	0.1	»	Isolated grains
Marcasite	0.1	—	—	—	»	»	0.8	0.5	—	—	»	2.1	Isolated grains	—	0.1	—	—
Siderite	40.3	—	25.9	—	—	—	—	—	—	—	—	34.7	—	—	—	—	—
Smithsonite	—	—	—	—	—	—	—	—	—	—	0.1	0.7	—	—	—	—	—
Malachite	—	—	Isolated grains	—	—	—	—	—	—	0.7	—	—	Isolated grains	—	—	—	—
Moissanite	—	—		Isolated grains	Isolated grains	Isolated grains	—	—	—	—	Isolated grains	Iso-lated grains	—	—	—	—	—
Wollastonite	—	—	—	—	—	—	—	—	—	—	—	»	-		—	—	—
Pyrrhotite	—	—	—	—	—	—	—	—	—	—	—	12.1	Isolated grains	Isolated grains	0.1	—	—

titanium, leads to the formation of large amounts of sphene and ilmenite. In addition to the rare earths, the crystal lattices of these minerals may contain, as isomorphic inclusions, ions of niobium and tantalum, which may be the reason for the absence of tantaloniobates in hybrid rocks.

The assimilation of foreign matter also usually leads to the enrichment of a granitic magma in iron; this, besides increasing the content of iron-magnesium rock forming minerals, also leads to the formation of large amounts of magnetite and, to a lesser extent, of pyrite.

At the same time, the content of such accessory ore minerals as scheelite, wolframite, cassiterite, sphalerite, galena and molybednite decreases or almost completely disappears in hybrid rocks. In view of the possible isomorphic replacement of Fe^{3+} by Mo^{4+} or Sn^{4+}, and of Fe^{2+} by Zn^{2+} or Pb^{4+}, it may be supposed that these elements have become dispersed, isomorphically replacing ions of iron in the lattices of magnetite or the dark-colored rock-forming minerals, so that the independent minerals have not been formed. On the other hand, it may be thought that when the magma assimilated the foreign matter it was not greatly enriched in these elements, as happened in the case of calcium, iron and titanium. In addition to these elements, almost all hybrid rocks have considerably increased (some ten times) contents of zircon, and thus also of zirconium, in the original hybrid magma. This is the only mineralogically notable case of enrichment of a magma in a rare element during the process of assimilation.

It is also characteristic that such minerals (usually considered contamination minerals) as garnet, sillimanite, andalusite and corundum are either absent in the contaminated rocks (corundum) or are present in extremely small quantities, usually smaller than the original amounts in normal granites (garnet).

The case of the assimilation of sediments with high aluminum content (Northern Caucasus) leads to the appearance of considerable quantities of andalusite, whereas the assimilation of limestones not only leads to increased contents of garnet but also causes the appearance of such calcium-containing minerals as vesuvianite, wollastonite and scheelite.

In this connection it is interesting to examine the relationship between the contents of rare-earth and calcium minerals. From the example of the slightly contaminated granites of the Northern Caucasus, one may see that at their contact with shales the granites are enriched in aluminum (resulting in the formation of considerable amounts of andalusites), but do not show greatly increased contents of iron, titanium or calcium, as may be seen in the almost unaltered contents of ilmenite, sphene and pyrite and the lower contents of magnetite, epidote and especially orthite. At the same time the content of monazite increases by a factor of ten or more (Table 3). This is the only case in which there is an increased content of monazite in slightly contaminated granite at the contact zone.

This same granite, at the contact with limestones, is characterized by a higher content of epidote, garnet, sphene, partially of orthite, and by the appearance of vesuvianite, wollastonite and scheelite. Here, where there is an abundance of calcium-containing minerals, one observes no concentration of independent rare-earth minerals.

In addition to the differences in their contents, the individual accessory minerals in normal and hybrid (contaminated) granites differ from each other in a number of morphological features.

Apatite. The prismatic crystals of this mineral in unaltered, but more often in hybrid, granitoids contain a mass of small black inclusions. The abundance of these inclusions is considered to be a very typical indication of apatite in hybrid rocks [21, 33]. Provincial peculiarities also occur. For example, although in the granitoids of the Urals the apatite crystals are formed of a prism $(10\bar{1}0)$, and more rarely a prism of the second order $(11\bar{2}0)$, a dipyramid $(10\bar{1}1)$ and frequently a basal pinacoid (0001), in the apatites from the granitoids of Tuva this basal pinacoid is encountered extremely rarely.

Zircon. In contrast to the normal specimens, the zircon of hybrid granitoids is characterized by very tiny inclusions of biotite or hornblende, usually located along the center of the crystal. Moreover the contact with limestones frequently contains crystals formed of short prisms, which are almost dipyramidal. The zircon from the granitoids of the Urals is represented by prismatic crystals formed of (110) and (111) prisms. Very rarely one may observe narrow faces of the prism (110) and the dipyramid (131). In the zircon from the Tuva granitoids, the chief forms are (110) and (111), and the (100) prism is very rarely developed.

Garnet. Garnet is encountered as irregular grains, and as crystals formed from (211) and (110). In normal granites these are, for the most part, yellowish-pink and light pink crystals with $N \approx 1.783$. In hybrid (contaminated) granites these are primarily red crystals with a refractive index N considerably greater than 1.780. At the contact with limestones there are many yellowish-green grains with $N \approx 1.744$.

Sphene. Sphene is represented by irregular segregations and flattened crystals of various colors — light pink, light cinnamon-brown and

yellowish-white. In hybrid contaminated granites the sphene has a darker color – reddish-cinnamon-brown, frequently containing a mass of small inclusions, among which magnetite and apatite may sometimes be identified.

CONCLUSIONS

1. The assimilation of foreign matter by a granitic magma leads not only to a change in the magma itself, but also to a redistribution of the rare elements in it, thus resulting in the formation of accessory minerals. The amount and composition of the latter is related to the scale and degree of the assimilation and the nature of the assimilated rocks.

Hybrid rocks are characterized by increased contents of apatite, zircon, orthite, epidote, ilmenite, sphene, magnetite and pyrite;[2] contaminated rocks also have increased contents of andalusite when argillaceous material has been assimilated, and of garnet, vesuvianite and wollastonite when calcareous material has been assimilated. Such relationships between the nature of the accessory minerals and the lithology of the surrounding rocks are extremely important in correlating granitic massifs by means of their accessory minerals, for massifs of the same age and related to the same intrusive stage, but penetrating various series of different lithologies, may also have different accessory minerals [23].

One must remember that corundum, andalusite and staurolite, whose presence is usually important evidence in favor of hybridism, are more rarely encountered than one might think from examining the literature. In the majority of cases these minerals are clearly of post-magmatic origin [39].

Since the assimilation of foreign material takes place at a time when the magma is in a molten and liquid state, and there is a direct relationship between the composition of the altered magma (increases in Ca, Mg, Fe, Ti) and of the accessory minerals (increases in Ca, Fe, Ti-containing minerals), we may quite properly infer that they are of magmatic, and in some cases post-magmatic origin.

It is impossible to agree with the view that the high content of accessory minerals in hybrid rocks may be the result of their entrance into the magma during the disintegration of xenoliths – that is, that they are xenocrystals [12, 37]. Study of the morphology of crystals of particular accessory minerals has shown that, even when there are differences in shape between the same mineral taken from various places (for example, zircon and apatite from Western Tuva and from the Middle Urals), such differences in the appearance of the individual minerals cannot be observed between hybrid and unaltered granites. Consequently, if xenocrystals are encountered, their significance in the total mass of accessory minerals is extremely small.

2. Among the ore accessory minerals, in the process of assimilation the granitoids are enriched chiefly in magnetite, ilmenite and pyrite, whose contents reach the greatest magnitudes. On the other hand, there is no increase in Sn, W, Pb, Zn and Mo minerals, even in such ore provinces as Chukotka [19] or the Eastern Transbaykal [9]. The dispersion of these elements in the crystal lattices of the iron-magnesium silicates, whose amount increases greatly in hybrid rocks, fully explains the observed relationships. At the same time the conclusion suggests itself that in the process of assimilation the magma was not essentially enriched in these elements. The increase in titanium and calcium-containing minerals in hybrid rocks causes such rare elements as niobium, tantalum and rare-earths to be dispersed in their crystal lattices, since the minerals of these elements disappear in hybrid granitoids. Thus hybrid rocks cannot contain large amounts of rare-metal accessory minerals. Only zircon is concentrated in them in amounts greater than its quantities in unaltered granites.

[2]This, of course, excludes the case of later epidotization or of hydrothermal impregnation of the unaltered granites by sulfides.

REFERENCES

1. Abdullayev, Kh. M., I. M. Isamukhamedov and I. Kh. Khamrabayev, Rol' protsessov assimilyatsii v formirovanii intruzivnykh kompleksov zapadnogo Uzbekistana. V. sb., Voprosy petrografii i mineralogii. [THE ROLE PLAYED BY PROCESSES OF ASSIMILATION IN THE FORMATION OF THE INTRUSIVE COMPLEXES OF WESTERN UZBEKISTAN. In the collection, PROBLEMS OF PETROGRAPHY AND MINERALOGY]: T. 1, 1953.

2. Babayev, K. L., Petrografiya Altyn-Tauskogo granitoidnogo massiva. [THE PETROGRAPHY OF THE ALTYN-TAU GRANITOID MASSIF]: Izd-vo Akad. Nauk UzSSR, 1954.

3. Baratov, R. B., O roli assimilyatsii v obrazovanii porod Yuzhno-Varzobskogo granitoidnogo massiva. [THE ROLE OF ASSIMILATION IN THE FORMATION OF THE SOUTHERN VARZOB GRANITOID MASSIF]: Soobshch. Tadzhiksk. Fil. Akad. Nauk SSSR, vyp. 20, 1949.

4. Belov, I. V., K voprosu o kontaminatsii (ksenogibridizme) granitov Kara-Tyube.

[THE PROBLEM OF THE CONTAMINATION (HYBRIDISM) OF THE KARA-TYUBE GRANITES]: Tr. Uzb. un-ta, t. 14, 1939.

5. Borisov, O.M., Rol' protessov assimilyatsii v formirovanii granitoidov G. Kalkanata. [THE ROLE OF ASSIMILATION PROCESSES IN THE FORMATION OF THE KALKANAT GRANITOIDS]: Izv. Akad. Nauk UzSSR, Ser. Geol., no. 4, 1957.

6. Vlasov, K.A., Osnovnyye geneticheskiye tipy redkometal'nykh mestorozhdeniy i faktory ikh obrazovaniya. [THE CHIEF GENETIC TYPES OF RARE-METAL DEPOSITS AND THE FACTORS IN THEIR FORMATION]: Izv. Akad. Nauk SSSR, ser. geol., no. 2, 1957.

7. Volovikova, I.M., Osobennosti veshchestvennogo sostava i formirovaniya granitoidov yugo-zapadnoy chasti Chatkal'skogo khrebta. [SOME ASPECTS OF THE MATERIAL COMPOSITION AND FORMATION OF THE GRANITOIDS IN THE SOUTHWESTERN PART OF THE CHATKAL RANGE]: Tr. In-ta geol. rudn. mestorozhd., petrogr., mineralogii i geokhimii, vyp. 21, 1958.

8. Dembo, T.M., Yavleniya anateksisa, gibridizma i assimilyatsii v kaledonskoy granodioritovoy intruzii sev. chasti Kuznetskogo Alatau. [MANIFESTATIONS OF ANATEXIS, HYBRIDISM AND ASSIMILATION IN THE CALEDONIAN GRANODIORITE INTRUSIVE IN THE NORTHERN PART OF THE KUZNETSKIY ALATAU]: Sov. geol., sb. 51, 1956.

9. Dolomanova, Ye.I., K voprosu ob assimilyatsii i granitizatsii peschanikoslantsevykh porod granitnymi intruziyami gipabissal'nogo tipa. [THE PROBLEM OF THE ASSIMILATION AND GRANITIZATION OF SANDSTONE-SHALE ROCKS BY HYPABYSSAL GRANITIC INTRUSIONS]: Sov. geol., sb. 51, 1956.

10. Yeliseyeva, O.P., Massiv aplitovidnykh granitov na yuzhnom sklone Kuraminskogo khrebta. [A MASSIF OF APLITIC GRANITES ON THE SOUTHERN SLOPES OF THE KURAMA RANGE]: Tr. In-ta geol. rudn. mestorozhd., petrogr., mineralogii i geokhimii, vyp. 21, 1958.

11. Zavaritskiy, A.N., Petrografiya Berdyaushskogo plutona. [PETROGRAPHY OF THE BERDYAUSH PLUTON]: ONTI, 1937.

12. Isamukhamedov, I.M., O priznakakh assimilyatsionnogo proiskhozhdeniya granitnykh porod. [SOME INDICATIONS OF THE ASSIMILATIONAL ORIGIN OF GRANITIC ROCKS]: Tr. Sredneaz. Un-ta, vyp. 63, geol. nauki, kn. 6, 1955.

13. Isamukhamedov, I.M., Petrologiya Nuratinsk. batolita. [PETROLOGY OF THE NURATINSK BATHOLITH]: Izd-vo Akad. Nauk UzSSR, 1955.

14. Kadenskaya, M.I., Problema assimilyatsii v sovremennom osveshchenii. [THE PROBLEM OF ASSIMILATION IN ITS PRESENT FORM]: Uch. zap. Leningr. Un-ta, t. 72, 1948.

15. Katkova, N.S., K voprosu o sostave varisskikh granitoidov v Terskey-Alatau (kokturpakskaya intruziya). [THE PROBLEM OF THE COMPOSITION OF THE VARISCIAN GRANITOIDS IN THE TERSKEY-ALATAU (THE KOKTURPAK INTRUSIVE)]: Izv. kirg. fil. Akad. Nauk SSSR, vyp. 4 - 5, 1947.

16. Koptev-Dvornikov, V.S., Yavleniya gibridizatsii na primerakh nekotorykh granitnykh intruziy paleozoya Tsentral'nogo Kazakhstana. [MANIFESTATIONS OF HYBRIDIZATION AS SEEN IN CERTAIN PALEOZOIC GRANITIC INTRUSIVES OF CENTRAL KAZAKHSTAN]: Tr. geol. In-ta Akad. Nauk SSSR, vyp. 148, Petrogr. ser., no. 44, 1953.

17. Lapchik, F.Ye., O roli nekotorykh mineralov v korrelyatsii magmaticheskikh porod. [THE ROLE OF CERTAIN MINERALS IN THE CORRELATION OF IGNEOUS ROCKS]: Mineralog. sb. L'vovsk. geol. O-va, no. 5, 1951.

18. Lodochnikov, V.N., K petrologii Voronezhskoy kristallicheskoy gliby Russkoy platformy. [THE PETROLOGY OF THE VORONEZH CRYSTALLINE BLOCK OF THE RUSSIAN PLATFORM]: Materialy po Obshchey i Prikladnoy geologii, vyp. 69, 1927.

19. Lugov, S.F., Voprosy vliyaniya assimilyatsii na rudonosnost' olovonosnykh intruziy Chukotki. [THE EFFECT OF ASSIMILATION ON THE ORE CONTENT OF THE TIN-BEARING INTRUSIVES OF CHUKOTKA]: Sov. geol., no. 10, 1958.

20. Luchitskiy, V.I., Assimilyatsiya i gibridizatsiya na territorii Ukrainskogo kristallicheskogo massiva. [ASSIMILATION AND HYBRIDIZATION WITHIN THE UKRAINIAN CRYSTALLINE MASSIF]: Tr. In-ta geol. Nauk Akad. Nauk SSSR, vyp. 107, no. 31, 1950.

21. Matkovskiy, O.I., Aktsessornyye mineraly granitoidov osnitskogo kompleksa Volyni. [ACCESSORY MINERALS IN THE GRANITOIDS OF THE OSNITSKIY COMPLEX IN VOLYN'YA]: Izd-vo L'vovsk. Un-ta, 1956.

22. Monich, V.K., Petrologiya granitnykh intruziy Bayanaul'skogo rayona v Tsentral'-nom Kazakhstane. [PETROLOGY OF THE GRANITIC INTRUSIVES IN THE BAYA-NAUL AREA OF CENTRAL KAZAKH-STAN]: Izd-vo Akad. Nauk KazSSR, 1957.

23. Nikol'skiy, A.P., Ob aktsessornykh mineralakh i nekotorykh mineralakh tyazhelykh fraktsiy v granitoidakh Altaya. v sb., petrologiya i mineralogiya nekotorykh rudnykh rayonov SSSR. [THE ACCESSORY MINERALS AND SOME MINERALS OF THE HEAVY FRACTIONS IN THE GRANITOIDS OF THE ALTAY. In the collection, PETROLOGY AND MINERALOGY OF CERTAIN ORE DISTRICTS OF THE USSR]: Gosgeolizdat, 1952.

24. Polkvoy, O.S., Protsessy kontaminatsii v Aksoranskoy granitnoy intruzii. [CONTAMINATION PROCESSES IN THE AKSORAN GRANITIC INTRUSIVE]: Izv. Akad. Nauk SSSR, ser. geol., no. 6, 1941.

25. Sokolov, G.A., Gibridnyy granito-gabbrovyy Shagir-Taratashskiy massiv na zapadnom sklone Srednego Urala. [THE SHAGIR-TARATASH HYBRID GRANITE-GABBRO MASSIF ON THE WESTERN SLOPES OF THE MIDDLE URALS]: Tr. petrogr. In-ta, vyp. 5, 1935.

26. Solov'yev, S.P., Raspredeleniye magmaticheskikh gornykh porod v SSSR i nekotoryye voprosy petrologii. [THE DISTRIBUTION OF IGNEOUS ROCKS IN THE USSR AND SOME PROBLEMS OF PETROLOGY]: Gosgeolizdat, 1952.

27. Khamrabayev, I.Kh., Ob aktsessoriyakh granitoidov Zapadnogo Uzbekistant. [THE ACCESSORIES IN THE GRANITOIDS OF WESTERN UZBEKISTAN]: Zap. uzb. otd. vses. mineralog. O-va, vyp. 12, 1958.

28. Khamrabayev, I.Kh., Aktsessornyye mineraly i rudonosnost' magmaticheskikh kompleksov. [THE ACCESSORY MINERALS AND ORE CONTENTS OF IGNEOUS COMPLEXES]: Izv. Akad. Nauk UzSSR, ser. geol., no. 3, 1957.

29. Khetchikov, L.N. and Ye.M. Ageyeva, Nekotoryye itogi izucheniya aktsessornykh mineralov granitoidov Valentinovskogo granitnogo massiva. [SOME RESULTS OF A STUDY OF THE ACCESSORY MINERALS IN THE GRANITOIDS OF THE VALENTINOV GRANITIC MASSIF]: Tr. Dal'nevost. fil. Akad. Nauk SSSR, ser. geol., t. 3, 1957.

30. Shtal', N.V., K petrologii mesozoiyskikh intruziy Vostochnogo Zabaykal'ya. v sb., petrologiya i mineralogiya nekotorykh rudnykh rayonov SSSR. [THE PETROLOGY OF THE MESOZOIC INTRUSIVES OF THE EASTERN TRANSBAYKAL. In the collection, THE PETROLOGY AND MINERALOGY OF CERTAIN ORE DISTRICTS IN THE USSR]: Gosgeolizdat, 1952.

31. Shcherba, G.N., Geologiya Narymskogo massiva granitoidov na Yuzhnom Altaye. [THE GEOLOGY OF THE NARYM GRANITOID MASSIF IN THE SOUTHERN ALTAY]: Izd-vo Akademii Nauk KazSSR, 1957.

32. Yurk, Yu.Yu., Petrologiya umanskogo i antonovskogo granitnykh plutonov. [THE PETROLOGY OF THE UMANSKIY AND ANTONOVSKIY GRANITIC PLUTONS]: Izd-vo Akad. Nauk USSR, 1953.

33. Baker, G., Apatite crystals with colored cores in Victorian granitic rocks Amer. Mineralogist, vol. 26, no. 6, 1941.

34. Backer, G., The heavy minerals in some Victorian granitic rocks. Proc. Roy. Soc. Victoria, vol. 54, 1942.

35. Boos, M., Some heavy minerals of the Front Range granities. J. Geol., vol. 43, no. 8, p. 2, 1935.

36. Brammal, A. and H. Harwood, The Dartmor granite: its mineralogy, structure and petrology. Mineral. Mag. vol. 20, 1923.

37. Croves, A., The heavy minerals of the Plutonic rocks of the Channel Islands. I. Jersey. Geol. Mag., vol. 64, no. 6, 1927.

38. Harker, A., Natural history of igneous rocks. London, 1909.

39. Hills, E., Andalusite and sillimanite in uncontaminated igneous rocks. Geol. Mag., vol. 75, no. 889, 1938.

40. Read, H., On the petrology of Arange district in Aberdeenshire. A study of assimilation. Quart. Geol. Sci., vol. 79, 1923.

Institute of the Mineralogy,
Geochemistry and Crystallochemistry of
Rare Elements of the
Academy of Sciences of the U.S.S.R.,
Moscow

Received May 29, 1959

THE FORMATION OF SPHEROIDAL LAVAS IN THE ACIDIC EXTRUSIVES OF THE KURAMINSK RANGE[1]

by

O. P. YELISEYEVA

A rather extensive literature has been devoted to the description of spheroidal lavas and their genesis; this has touched mainly upon rocks of basic and ultrabasic composition. The majority of investigators believe that the spheroidal structure of lavas is due to changes in the magma under submarine conditions. For example, M.A. Kashkay and I.A. Babayev [8] have studied the spheroidal lavas of Azerbaydzhan, which are an accumulation of globular bodies ranging in diameter from 10 cm to 1 m. After studying the stratigraphic section, these authors believe that the magma which produced these spheroidal lavas was extruded under water.

A voluminous paper by M.A. Gilyarova [4] examines the spheroidal lavas of the Suisar region of Southern Kareliya and their genesis. M.A. Gilyarova presents a critical review of the literature touching upon this problem. One of the necessary conditions for the formation of spheroidal lavas the author believes to be a high content of volatile components, meaning that they are associated chiefly with rocks of the spilitic series.

The formation of the spheroidal lavas along the middle reaches of the Lower Tunguska River is the subject of an article by V.I. Kudryashova [10], who describes the spheroidal lavas of basic rocks of the spilitic type. The author believes that the spheroidal lavas are the product of rapid cooling in an aqueous medium.

The spheroidal lavas of the Siberian platform have been described by Ye. Ya. Kiyevlenko. The spheroids are composed of fine-grained basalt or mandelstone and are surrounded by a friable clastic ground mass. The author concludes that these spheroidal lavas were formed by volcanic effusions in shallow-water basins.

A deposit of spheroidal lavas in the valley of the Kebin River in the Kirghiz SSR has been studied by M.V. Zanin [7]. Here the spheroidal lavas have an acidic composition and occur at the contact between granites and shales. The author believes that these spheroidal lavas are endormorphic formations produced by the action of a granitic magma upon the shales.

Two articles by F.Yu. Levinson-Lessing [12, 13] are devoted to the variolites of Yalguba. The variolites are a variety of diabase, similar to porphyrite. In this author's opinion, the variolites of Yalguba are the result of a peculiar type of sharp differentiation, separating the original magma into two products: one enriched in silicic acid and alkalies, and the other lacking alkalies and enriched in alkali earths, ferrous iron and water. The differentiation was due to liquation occurring in the form of an emulsion, in the formation of which water played some, and perhaps an important, role.

The formation of spherulitic rocks, mainly the so-called drop-shaped spherulites, is explained by many authors by the liquation of the magma into two immiscible liquids. For example, D.S. Belyankin [1] believes that in the formation of igneous spherulites there may have been liquation in such cases in which the crystallization of the spherulites was very slight and showed no clear radial-acicular structure.

A fairly complete description of the spherulitic porphyries is presented by I.M. Volovikova [3] for the intermediate and acidic extrusives developed in the Kuraminsk and Chatkal Ranges. The author believes that the drop-shaped spherulites were formed before the solidification of the rock, during the separation of matter rich in alkalies, in the form of emulsion drops which later merged into a continuous layer.

An article by V.I. Lebedinskiy and Mo Kemin' [11] is devoted to the phenomena of liquation in the lavas of the Kalgan complex (Chinese Peoples Republic). The drop-shaped spherulites of these acidic glassy lavas, in the authors' opinion, were formed as a result of liquation of the lava close to the surface.

---

[1]Ob obrazovanii sharovykh lav v kislykh effuzivakh Kuraminskogo khrebta.

The present article is devoted to the spheroidal lavas of the Kuraminsk Range, developed in the quartz porphyries of the Kyzylnura volcanogenic-sedimentary formation.

The Kyzylnura formation, which contains the youngest effusive rocks, is extensively developed both in the Kuraminsk and in the Chatkal Ranges. It was first discovered in 1944 by N. P. Vasil'kovskiy and Z. P. Artemova [2] from its unconformable occurrence upon the Ravash formation east of the Kyzyl-Nur peak in the Chatkal Range. The precise age of this formation has not been determined, because of the lack of organic remains. Since it overlies the Ravash formation, which is Upper Permian, on the one hand, and since the eroded surface of the Kyzylnura rocks in the Angren region is covered by Jurassic carbonaceous deposits on the other hand, it may be assumed that the Kyzylnura formation was formed in the Early Triassic. The greatest thickness of this formation is 1 km.

The Kyzylnura formation, which we have studied in the areas of the Aygyr-Baytal and Kyzyl-Su Rivers (Kuraminsk Range) is a complex volcanogenic sequence which has been divided by P. N. Podkopayev and A. S. Makarov (1950) into two members — an upper and a lower. The basis of this subdivision is the presence of a layer of tuff deposits with interformational conglomerates. The thickness of the formation in this area is approximately 650 m. The lower subsuite is composed chiefly of welded tuffs, with smaller amounts of brecciated and felsite porphyries. The lower part of the upper member contains a stratum of tuffs which dips 20 - 25° westward or northwestward and is represented by alternating interlayers of tuffaceous sandstones and welded tuffs of quartz porphyries. This indicates that the initial sedimentation gave way to cyclical volcanic activity. This is followed by a sequence, some 100 m thick, consisting of coarse, medium and fine sandstones alternating with tuffaceous conglomerates, tuff breccias, siliceous and tuffogenic schists. The top of the tuffaceous sediment series is conformably overlain by spherulitic porphyries, welded tuffs and quartz porphyries.

The spheroidal lavas described in this article were observed in the upper subformation of the Kyzylnura formation, exposed on the left bank of the left tributary of the Kyzyl-Su River. Here (from bottom to top) one may distinguish the foloowing varieties of rock: welded tuffs of quartz porphyries with areas of spherulitic quartz porphyries, brecciated quartz porphyries with lenses of fluidal welded tuffs, lithocrystalloclastic welded tuffs and brecciated lavas of quartz porphyries, spheroidal lavas, brecciated quartz porphyries and, finally, dense light-pink quartz porphyries.

The layer of spheroidal lavas, whose greatest thickness is no more than 15 - 20 m and which extends for 100 m, may be traced discontinuously in the form of extended lenses. It consists of spheroidal formations, from 1 to 35 cm in diameter, with spherules 10 - 15 cm in diameter being the most common. The surfaces of the larger spheres are uneven, and covered by incomplete small spherules (verrucous). Frequently one observes intergrown spheres which form a crust over the spherulitic porphyries. The spheroidal formations are sharply set apart from the mass of rock cementing them, so that they are easily broken out with the hammer or else readily weather out, leaving characteristic rounded cavities.

The spheroids are composed of reddish-cinnamon-brown quartz porphyry. There is no concentric structure, but the marginal parts of certain spheres have a darker color which is due to the content of greater amounts of ferric iron. In particular cases the central parts of the spheroids contain small (up to 1 cm in diameter) inclusions of acidic rock of extrusive appearance (Figure 1).

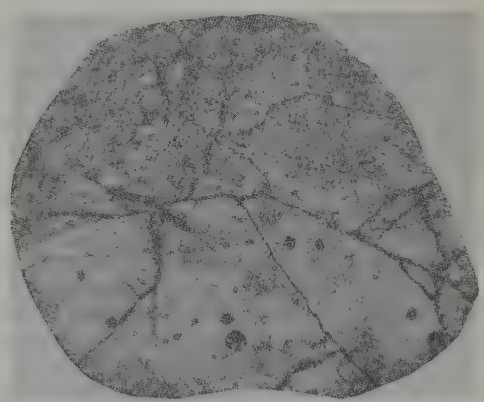

FIGURE 1. Spheroidal formation, lacking any concentric structure. Natural size.

The spheroidal formations are unevely distributed, but considerably exceed the amount of cement, which composes no more than 10 to 20% of the rock's volume. The cement of the spheroidal lavas is spherulitic porphyry. The underlying rocks are represented by welded tuffs of quartz porphyry, and the overlying rocks are well crystallized quartz porphyries.

The spheroidal formations were studied petrographically in large thin sections (3 x 7 cm, 5 x 5 cm), in which their structure could be observed from the periphery to the center. Not one of the thin sections studied showed any concentric structure.

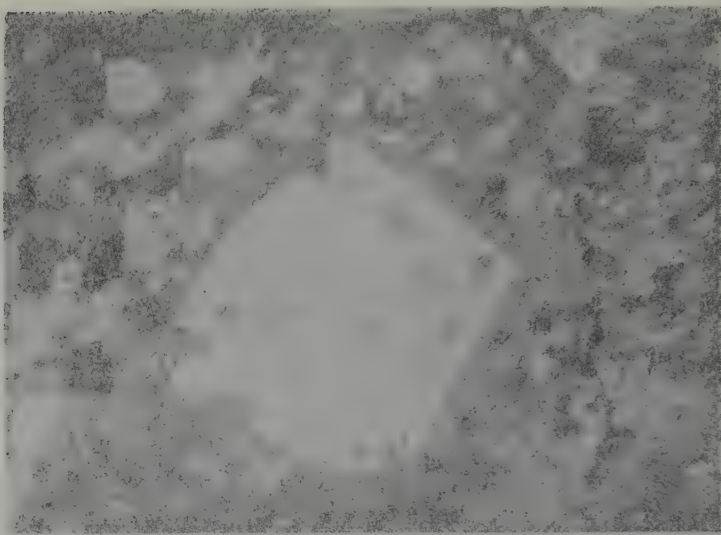

FIGURE 2. Porphyritic structure of spheroidal formation. The structure of the ground mass is felsitic, with plumose ingrowths of felspathic composition. Magnification x 10, crossed nicols.

The spheroidal formations have a porphyritic structure with a felsitic ground mass, containing feather-like growths apparently of felspar (Figure 2). Disseminations some 0.5 to 2 mm in diameter compose 1 to 3% of the volume of the rock, and are represented chiefly by quartz, and to a lesser degree by felspars.

The quartz has angular contours, and usually shows deep basin-shaped cavities and inclusions of the ground mass, and contains fine gas-liquid inclusions, and in particular cases inclusions of small idiomorphic prisms of zircon.

The potassium felspar is represented by pelitized and perthitized tabular grains partially separated by the quartz. Some of the grains are accompanied by fringes of micropegmatite.

The plagioclase, like the potassium felspar, has a tabular shape, and is intensively sericitized and replaced by iron carbonate and oxides.

The ground mass consists of felsitic "pillows" of quartz, sometimes with denticular outlines. The quartz contains numerous subparallel oriented plumose ingrowths, which are apparently the cavities left by felspar crystals. The felspathic plumose ingrowths have a refractive index lower than that of quartz and Canada balsam. The quartz of the ground mass is highly clouded by numerous inclusions, creating the impression of a mist. The rock contains dispersed ion oxides, which are most frequent in the marginal parts of the spheroidal formations.

In addition to the spheres, the spheroidal lavas have been observed to contain smaller similar formations, which are drop-shaped spherulites.

The drop-shaped spherulitic porphyry consists of spherulites, surrounded by a felsitic groundmass and composing some 40 to 60% of the rocks' volume. These spherulites have irregular shapes, frequently very elongated, with curiously convoluted outlines. Rounded spherulites are very rarely encountered (Figure 3). The drop-like spherulites frequently merge into each other, forming short discontinuous zones some 2 to 7 mm in size.

The centers of the spherulites sometimes contain inclusions. Among the drop-like spherulites composed entirely of volcanic glass (slightly active in polarized light), and spherulites whose centers are felsitic. The refractive indices of the spherulites are lower than that of Canada balsam. Occasional rare inclusions in the drop-like spherulites are represented by tabular potassium felspar, some 2 mm in size, to a great degree replaced by pelite and carbonate (the latter developed both after the disseminations and along tiny fractures in the spherulites), and by quartz grains 0.5 - 2.5 mm in size. These grains are of irregular shape, but are frequently rounded with embayments and inclusions of glassy material.

The ground mass containing the drop-like spherulites has a felsitic quartz-felspar composition. It contains flow structures reflected in the banded distribution of the disseminations and in the alternation of bands enriched with

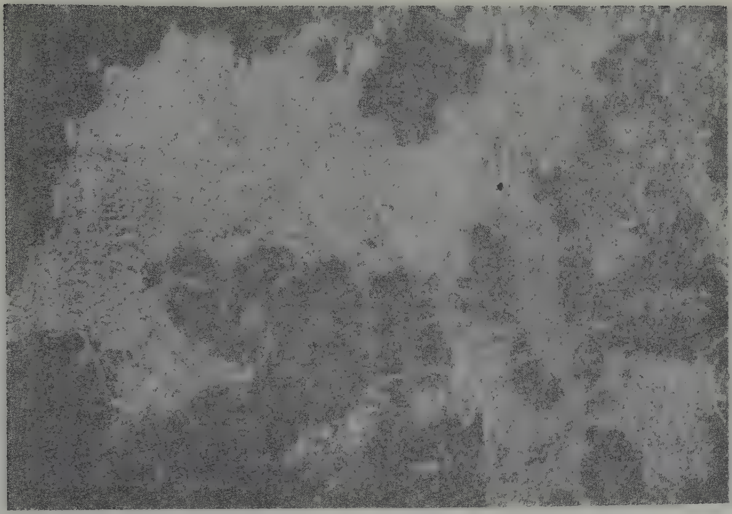

FIGURE 3. Drop-shaped spherulitic porphyry (spherulites are dark). Magnification x 10, crossed nicols.

quartz and felspar. The flow bands envelop the drop-like spherulites: this indicates that the latter were formed before the rock had completely solidified. The ground mass contains areas filled with fine lamellae of sericite and finely dispersed iron oxides.

The cement of the spheroidal lavas is composed of secondary spherulitic porphyry, whose formation is not associated with instantaneous crystallization of the rock, but is the result of devitrification. For the sake of simplicity, we have included them in the group of branching spherulites.

The ramose spherulitic porphyry consists of spherulites some 2 to 4 mm in diameter. The spherulites compose 40 to 60% of the volume of the rock (Figure 4).

To the naked eye, the central parts of the spherulites appear darker than their edges. These often contain tabular grains of felspar, which surround the radial acicular branches of felspathic substance adjoining the felspar crystals; along these radiating needles are developed flakes of chlorite, which give the centers of the spherulites their darker color. The shape of the spherulites in most cases is rounded, and more rarely ellipsoidal. The branches of felspathic matter in the central parts are more closely packed together and directly adjoin each other, whereas toward the margins they have the appearance of diverging rays, the spaces between them filled with glass that is recrystallized into felsite. The outlines of the spherulites are formed by the curiously terminating branches of felspathic matter (Figure 5).

In some cases the centers of the spherulites do not contain felspar inclusions, but chlorite flakes are developed in all of the spherulites without exception. Their edges, between the felspar branches, frequently contain iron oxides which also fill the thin fractures intersecting the felspar branches.

The spherulites are surrounded by a felsitic mass of quartz-felspar composition with a slight fluidal structure emphasized by the irregular distribution of ore dispersions, and by the direction of the more crystallized quartz-felspar lenses.

In the Central Chemical Laboratory of the Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the Academy of Sciences of the U.S.S.R. the chemist I. Nikitina made chemical analyses of the spheroids (from the central and marginal parts) and of the cementing mass. Moreover individual ramose spherulites and felsitic ground mass samples were selected and analyzed separately (Table 1).

The results have shown that the spheroidal formations, especially their edges, are distinquished from the cementing ramose spherulitic porphyry by their great content of silicic acid, which amounts to 90.57%, and by their much small contents of aluminum and alkalies, chiefly potassium. The more intensive coloration in the margin of the spheroids is due to increased amounts of ferric iron, whose content increases from 0.51% at the center to 0.76% at the edges.

The ramose spherulites from the spherulitic porphyry were separated under a binocular lens. In this separation of the spherulites, the felspar

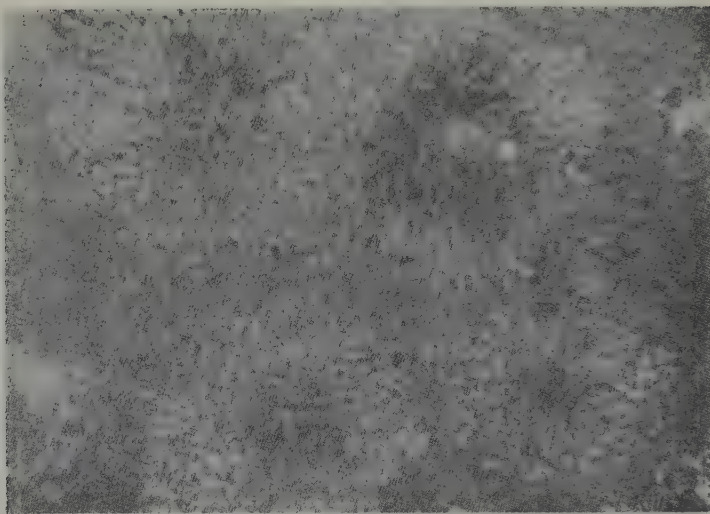

FIGURE 4. Ramose spherulitic porphyry cementing spheroidal formations. Magnification x 10, parallel nicols.

needles were easily broken off, so that the chemical analysis (945-a) reflects chiefly the composition of the felspar needles.

The chief differences between the ramose spherulites and the ground mass between them consists in smaller amounts of silicic acid in the spherulites, along with larger amounts of aluminum, potassium oxide and water. Such differences in the composition of the spherulites and the cementing mass are not characteristic.

On the one hand, according to D. S. Belyankin [1], who noted that igneous spherulites are not completely identical chemically with their ground mass between them, the chief differences are observed in the silicic acid, water and alkalies. On the other hand, the spherulites are usually more acidic than glass, and contain less water; as regards the alkalies, although their total is the same in the ground mass and the spherulites, Na_2O predominates in the spherulites and K_2O in the glass. Similar data on

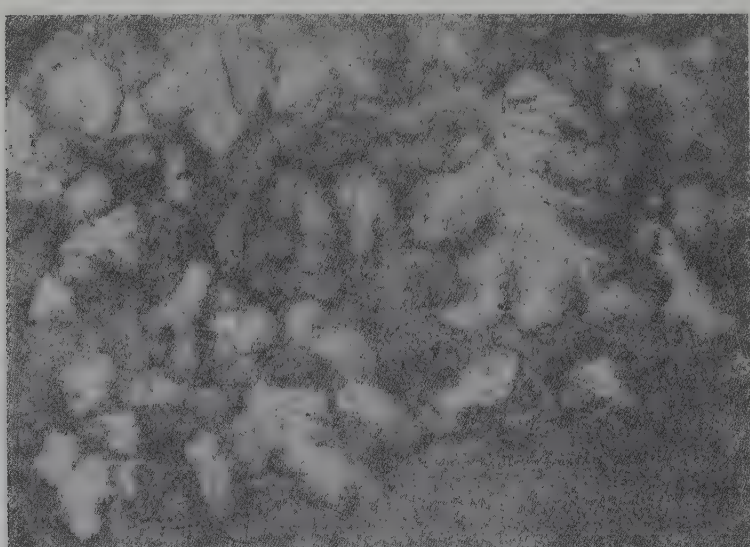

FIGURE 5. Outer end of ramose spherulite. Magnification x 90, parallel nicols.

Table 1

Results of chemical analyses of spheroidal lavas

Oxides	Spheroidal formation, central part, sp. 929-b	Spheroidal formation, outer part, sp. 929-a	Spherulite, porphyry, sp. 945	Ramose spherulites from spherulitic porphyry, sp. 945-a	Interspherulitic mass, sp. 945-b
SiO_2	83.24	90.57	76.96	75.24	79.58
TiO_2	0.01	0.01	,0.01	0.01	0.01
Al_2O_3	8.49	5.00	12.38	13.19	11.03
Fe_2O_3	0.51	0.76	0.52	0.63	0.68
FeO	0.30	0.30	0.38	0.57	0.30
MnO	0.01	0.01			
MgO	0.07	0.07	0.06	0.07	0.04
CaO	0.32	0.38	0.34	0.54	0.44
Na_2O	0.12	0.12	0.21	0.23	0.23
K_2O	6.30	2.65	8.29	8.39	7.29
H_2O^-	0.08	0.06	0.18	0.34	0.28
H_2O^+	0.67	0.33	0.94	1.35	0.68
F*	None found	None found	None found	None found	None found
Cl	Traces	Traces	Traces	Traces	Traces
Total	100.12	100.26	100.27	100.56	100.54

*Fluorine in the composition of fluorite; the latter was found in pulverized spheroidal formations (sp. 929-a and 929-b).

the chemical composition of spheroidal crystals and their connecting ground mass are also to be found in a paper by I.M. Volovikova [3]. According to her data, the spherocrystals are characterized by larger amounts of silicic acid and alkalies and smaller quantities of aluminum, iron, magnesium and water.

For a more detailed study of the composition of the spheroidal lavas, we have taken two synthetic concentrate samples, each weighing 10 kg, one of the spheroids and the other from the spherulitic porphyry cementing them. From these samples, the heavy fractions were separated and studied. The following minerals[2] were observed in the spheroidal formations: fluorite - chief mineral, pyrite - 20%, cyrtolite - 20%, zircon - 20%, apatite - 1%, epidote - 1%, copper oxides - traces, leucoxene - traces, uranothorite - traces and galena - traces. The heavy fraction of the cementing spherulite porphyries consists of zircon - chief mineral, pyrite - 10%, apatite - 1%, leucoxene - 1%, chloritized biotite - 1%, epidote - 0.5%, hornblende - traces, and fluorite - traces.

A comparison of the accessory minerals shows that the spheroidal formations are characterized by the presence of fluorite, forming most of the concentrate, whereas zircon predominates in the spherulitic porphyry, and fluorite is present only as traces.

On the basis of what has been said above, it is suggested that these acidic spheroidal lavas, in contract to similar formations of basic rocks in other areas, were formed under terrestrial conditions.

It is most likely that the formation of the spheroidal lavas is due to the liquation of a silicate melt into two immiscible layers, which most probably occurred before the lava had been poured out onto the surface. At the moment of outpouring, when the quartz and felspar phenocrysts were crystallized, there existed favorable conditions for the separation of a layer, part of which, because of surface tension, tended to assume the form of a sphere.

Liquation of the magma facilitated the uneven distribution in the melt of volatiles, particularly fluorine, whose residue at the present time is fixed in the spheres in the form of accessory fluorite, and also a favorable combination of other factors — the chemical composition and a sharp change in temperature and pressure during the outpouring of the lavas.

Nevertheless the presence of a large amount of fluorine without the combination of other factors will not cause liquation. As an example, we may cite the extrusive quartz porphyries of

[2]The percentage contents of the minerals in relation to the yield of the concentrate have been determined visually.

Mt. Sherlova (Ye.I. Dolomanova), which in spite of the presence of fluorine in the magma, fixed in the rock as accessory fluorite, show no indications of liquation. The formation of the drop-like spherulites, which are the analogues of the spheroids but of different size, is due to the formation of two immiscible liquids, in which the solidification of the drop-like spherulites somewhat preceded the solidification of the ground mass between them, as indicated by the flow bands which envelop the drop-like spherulites. In a number of cases these spherulites represent completely crystallized glass, differing in composition from the ground mass (the refractive index of the spherulites is lower than that of the ground mass). One may also trace transitions from glassy spherulites to spherulites whose centers are crystallized to felsite. The drop-like spherulites were undoubtedly liquid, as testify by their tendency to merge when they are in contact with each other.

The formation of the ramose spherulites, which have a concentric-radial structure and develop around some center of crystallization, in this case represented by quartz and felspars, is most likely caused by devitrification of the volcanic glass.

As early as 1937 experiments by D.P. Grigor'yev [5] confirmed the possibility of liquation occurring in melts, whose composition is close to that under natural conditions. For example, under laboratory conditions he succeeded in obtaining a fine emulsion of two immiscible liquids from a fluorine-containing melt.

Similar experiments have been made recently by Ya.I. Ol'shanskiy [14] and Z.P. Yershova [6]. They cite data on the boundaries of the layering in the system $CaO-Na_2O-SiO_2$, when all the O^{2-}-ions are replaced by F^--ions. Z.P. Yershova believes that the area of liquation includes the majority of compositions of rocks, and assumes the possibility of liquation occurring in igneous melts.

REFERENCES

1. Belyankin, D.S., O sferolitakh v tekhnicheskom stekle i o nekotorykh sharovykh obrazovaniyakh v magmaticheskikh gornykh porodakh. [SPHERULITES IN PYREX GLASS AND SOME SPHEROIDAL FORMATIONS IN IGNEOUS ROCKS]: Tr. petrogr. In-ta Akad. Nauk SSSR, vyp. 4, 1933.

2. Vasil'kovskiy, N.P., Stratigrafiya i vulkanizm verkhnego paleozoya yugo-zapadnykh otrogov Severnogo Tyan'-Shanya. [THE STRATIGRAPHY AND VOLCANIC ACTIVITY OF THE LATE PALEOZOIC IN THE SOUTHWESTERN SPURS OF THE NORTHERN TYAN'-SHAN']: Izd-vo Akad. Nauk UzbSSR, 1952.

3. Volovikova, I.M., Sferolitovyye obrazovaniya v verkhnepaleozoyskikh effuzivnykh porodakh Chatkal'skogo khrebta. [SPHERULITIC FORMATIONS IN THE UPPER PALEOZOIC EFFUSIVE ROCKS OF THE CHATKAL RANGE]: Tr. In-ta geol. nauk, vyp. 159, Petrogr. ser., no. 32, 1955.

4. Gilyarova, M.A., Sharovyye lavy Suysarskogo rayona Yuzhnoy Karelii i problema genezisa sharovykh lav. [THE SPHERULITIC LAVAS OF THE SUYSAR DISTRICT IN SOUTHERN KARELIYA AND THE PROBLEM OF THE GENESIS OF SPHERULITIC LAVAS]: Uch. zap. leningr. Un-ta, 268, 1959.

5. Grigor'yev, D.P., and Ye.V. Iskyul', Differentsiyatsiya nekotorykh silikatnykh rasplavov, kak resul'tat obrazovaniya dvukh nesmeshivayushchikhsya zhidkostey. [THE DIFFERENTIATION OF CERTAIN SILICATE MELTS AS A RESULT OF THE FORMATION OF TWO IMMISCIBLE LIQUIDS]: Izv. Akad. Nauk SSSR, Otd. Matem. i yestestv. nauk, no. 1, 1937.

6. Yershova, Z.P., Issledovaniye ravnovesiy nesmeshivayushchikhsya zhidkostey vo ftor-silikatnykh rasplavakh. [A STUDY OF THE EQUILIBRIUM OF IMMISCIBLE LIQUIDS IN FLUOSILICATE MELTS]: Dis. Kand. Geol.-Min. nauk, 1958. In-t geol. rudn. mestrozhd., petrogr., mineralogii i geokhimii.

7. Zanin, M.V., O nakhodke mestorozhdeniya sharovykh porfirov v doline r. B. Kebin Kirgizskoy SSR. [THE DISCOVERY OF A DEPOSIT OF SPHEROIDAL PORPHYRIES IN THE VALLEY OF THE BOL'SHOY KEBIN RIVER IN THE KIRGHIZ SSR]: Zap. vseros. mineralog. O-va, no. 2, ch. 70, 1941.

8. Kashkay, M.A., and I.A. Babayev, O sharovykh lavakh Azerbaydzhana. [THE SPHEROIDAL LAVAS OF AZERBAYDZHAN]: Izv. Akad. Nauk AzerbSSR, ser. Geol.-Petrogr. nauk, no. 5, 1958.

9. Kiyevlenko, Ye.Ya., O sharovykh lavakh Sibirskoy platformy i svyazannom s nimi mineraloobrazovanii. [THE SPHEROIDAL LAVAS OF THE SIBERIAN PLATFORM AND THE MINERAL FORMATIONS ASSOCIATED WITH THEM]: Tr. Vses. N.-I. In-ta P'yezooptich. Mineral'n. Syr'ya, t. 2, vyp. 1, 1958.

10. Kudryashova, V.I., K voprosu ob obrazovanii sharovykh lav srednego

techeniya r. Nizhney Tunguski. [THE PROBLEM OF THE FORMATION OF THE SPHEROIDAL LAVAS ALONG THE MIDDLE REACHES OF THE LOWER TUNGUSKA RIVER]; Izv. Akad. Nauk SSSR, ser. geol., no. 2, 1958.

11. Lebedinskiy, V.I., and Mo Ke-min', O yavleniyakh likvidatsii v lavakh Kalanskogo kompleksa (KNR). [MANIFESTATIONS OF LIQUATION IN THE LAVAS OF THE KALGAN COMPLEX (CHINESE PEOPLE'S REPUBLIC)]: Izv. Akad. Nauk SSSR, ser. geol., no. 12, 1958.

12. Levinson-Lessing, F.Yu., Variolity Yalguby Olonetskoy gubernii. [THE VARIOLITES OF YALGUBA IN THE OLONETS GUBERNIYA]: Izb. tr., t. 1, 1952.

13. Levinson-Lessing, F.Yu., O svoyeobraznom tipe differentsiatsii v variolite Yalguby. [A PECULIAR TYPE OF DIFFERENTIATION IN THE YALGUBA VARIOLITE]: Iab. tr., t. 1, 1952.

14. Ol'shanskiy, Ya.I., O vzaymodeystvii kremnezema c ftoridami metallov. Tr. 5-go soveshch. po eksperim. i teknich. mineralogii i petrografii. [THE REACTIONS BETWEEN SILICA AND FLUORIDES OF METALS. IN TRANSACTIONS OF THE FIFTH CONFERENCE ON EXPERIMENTAL AND ENGINEERING MINERALOGY AND PETROGRAPHY]: Izd-vo Akad. Nauk SSSR, 1958.

Institute for the Geology
of Ore Deposits, Petrography,
Mineralogy and Geochemistry of the
Academy of Sciences of the U.S.S.R.,
Moscow

Received September 7, 1959

DERIVATION OF DIAGRAMS FOR THE OPTICAL ORIENTATION OF ACIDIC AND INTERMEDIATE PLAGIOCLASES [1]

by

A. S. MARFUNIN

SOME CONCEPTS OF THE PHASE RELATIONSHIPS WITHIN THE FELDSPAR GROUP AND THE ORIGINAL PREREQUISITES FOR THE CONSTRUCTION OF DIAGRAMS FOR THE OPTICAL PROPERTIES OF THE PLAGIOCLASES

Twice during the course of almost a century there have been changes in the basic conception of the feldspar group. The first time the change was brought about by the mineralogical-chemical investigations of the distinguished Czech mineralogist and petrographer, H. Tschermak [16]. He showed that the felspars are not individual chemical compounds, but mixtures of three components — albite, anorthite and orthoclase. His paper, which was published in the age of the chemistry of preparations (compounds) and reflected the methods typical of that age, presented conclusions that to a great extent were ahead of their time and gave rise to a discussion that continued to the end of the century. This was, in essence, the famous controversy between J. L. Proust and K.L. Bertollé, transferred to the field of mineralogy.

The diagram for the composition and physical state of the plagioclases derived by N. L. Bowen in 1912, as well as the development of physicochemical analysis, completed the formation of the conceptions of this group of minerals which lasted until the last few years.

The second change in the principles governing the study of the feldspars was due to the X-ray structural investigations carried out mainly during the 1950's by S. Kh. Chao, and V. Kh. Taylor, F. Lavaisse and Yu. R. Goldschmidt, N.L. Bowen and O. F. Tattle, V. F. Kohl, Kh. Serum, P. Gay and others [9]. The data obtained by these scientists made it possible to relate the structural transformations within the feldspars to a thoroughly studied category of phenomena — the successive regulation of solid solutions.

The construction of diagrams of the optical orientation of the plagioclases is one of the classical problems of petrography. During a period of about seventy years different variants of the solution to this problem were proposed by M. Schuster, Ye. S. Fedorov, F. Bekke, M. A. Usov, L. Duparc, M. Reingard, V. V. Nikitin, K. Burry, A. N. Zavaritskiy, V. S. Sobolev and other investigators. The resulting diagrams differed in the principles by which the data underlying the diagrams were selected, in the methods of treating the materials and in the means of depicting the optical orientations.

Nevertheless these diagrams had one main feature in common: they proceed from the same presuppositions, which are associated with the pre-X-ray structural conceptions of the phase relationships in the felspar group. The differences between them do not exceed the limitations formed by these conceptions. They are based on the following supposition: that the optical properties of the plagioclases are a continuous function of the composition; in particular, that each plagioclase of given composition has a corresponding specific and single orientation of the optical indices.

These diagrams, in essence, do not take into account the possibility of any deviation from the curves that express the relationship between the optical orientation and the composition. The deviations actually observed were considered to be the results of errors in measurement, of the presence of admixtures of other components, of "anomalies" caused by the different volumes of the albite and anorthite molecules, of stresses, etc.

This supposition is contradicted by the very existence of the different variants of the curves, which differ from each other to a greater degree than that attributable to errors of measurement. Another contradictory aspect is the mentions of the "average" nature of the curves (average of which measurements?).

In addition to the non-directional deviations from the supposed curves, there have also been systematic deviations in one direction or another

[1] Vyvod diagrammy opticheskoy oriyentirovki kislykh i srednikh plagioklazov.

in the optical orientations of the plagioclases from effusive rocks [2, 3, 12].

It appeared that the solution to this problem was found by A. Keiler [14], who made the suggestion, as an empirical generalization, that there are two categories of optical properties among the plagioclases: "low-temperature" (in the plagioclases of intrusive and metamorphic rocks) and "high-temperature" (in the plagioclases of extrusive rocks). He showed that the then existing graphs could be used only to determine the composition of the "low-temperature" plagioclases, whereas special curves were constructed for the "high-temperature" plagioclases of intermediate composition, and were later reconstructed by G. Tertsch for the acidic and basic members of this series. K. Burry's diagram for the "high-temperature" plagioclases, which differs in its method of treating the data, is based on this supposition, and in the case of the "high-temperature" varieties also on the same materials.

On the other hand, the division of the plagioclases into "high-temperature" and "low-temperature" varieties does not take account of any deviation from these two types and does not indicate any internal factors determining this division. The data are not entirely accounted for by this generalization:

1) Numerous measurements show that the points are not concentrated about any two curves, but form a continuous zone. Scattering of the points exceeding the error in measurement is observed on the diagrams reflecting the optical properties of the plagioclases in any rock — intrusive, extrusive or other.

2) Transitional types between typical "high-temperature" and "low-temperature" varieties were obtained by roasting. The transitional state has been marked by optical and X-ray methods [9].

3) Natural plagioclases with transitional optical properties [9] have also been described.

The observations of the optical orientation independent of the composition yielded results very close to the true nature of the phenomena. Nevertheless this nature was discovered only when, as a result of the above-mentioned X-ray structural studies, the cause of the changes was found in the phenomenon of regular successiveness.

It should be noted that V.S. Sobolev [10, 11] was the first to mention the possibility of a connection between the changes in the angle of the optical axes of the plagioclases and the formation of suprastructural (successive) solid solutions.

Proceeding from the conception of the plagioclases as successive solid solutions, we may formulate some new presuppositions for the preparation of diagrams of the optical properties of the plagioclases.

The optical properties of the plagioclases are a continuous function of the composition and the degree of successiveness; in particular, for each plagioclase of a given composition and degree of successiveness there is a corresponding orientation of the optical indices.

I. THE DATA

1. A Summary of the Data on the Optical Orientations of the Plagioclases of Acidic and Intermediate Composition

Table 1 contains a summation of the data in the literature over a period of more than fifty years on the optical orientations of chemically analyzed plagioclases, as well as plagioclases whose composition was determined by very precise measurements of the refractive indices. For all the samples included in the summary, the optical constants have been cited in the same form (the constants not cited in the original papers have been computed graphically, using a magnified Wulf net with a diameter of 40 cm).

The coordinates of the A and B optical axes may be constructed by means of the Wulf net, using the elements of the indices in the projection on the $\perp$[001] plane. The crystallographic lines $\perp$(010), [001] and $\perp$[001] $\|$ (010) were selected as the axes of the most common twinning laws, permitting full determination of the complete orientation of the indices. The Eyler angles are suitable for analytical computations and have been used in the present article in treating the material. A summary of the Eyler angles is cited in the paper by K. Burry [12]. We have recomputed them anew in our calculation of the other constants; there are some discrepancies between our results and the values cited by Burry, but these are negligible.

In regard to the optical properties of the "high-temperature" plagioclases, we must dwell for a moment on a misconception of rather long standing. Of the total number of 16 specimens with "high-temperature" optics, 12 are among the well-known plagioclases from Lake Linosa. In 1940 H.S. Washington and F.E. Wrignt (see 13) discovered some peculiar properties in these plagioclases: the specific weight, the crystallographic angles and the light refraction corresponded to No. 50, but the extinction angles to No. 40. The chemical analyses were not susceptible to recomputation as orthoclase, albite and anorthite, with an excess of alkali. To explain these peculiarities, it was suggested that the solid solution contained a nepheline molecule in its high-temperature

Table 1

Optical Orientations of Acidic and Intermediate Plagioclases

%An	A		B		⊥ (010)			[001]			⊥ [001] (010)			Φ	Ψ	Θ	Reference
	λ	φ	λ	φ	α	β	γ	α	β	γ	α	β	γ				
0	+62.3	−24.2	+83.0	+32.0	18.5	72.0	86.0	−71.25	26.5	73.0	−88.0	72.25	18.0	94.5	109.4	72.5	F. Lavaisse and U. Chaisson, 1950
0.5	+64.2	−49.1	−76.5	−47.8	17.0	73.0	−89.3	−73.2	18.0	84.0	−88.0	84.0	6.1	89.7	107.8	84.0	O. Grosspitsch, 1905
1.2	+63.75	−48.3	−77.1	−47.2	16.5	74.0	−89.3	−73.75	18.0	83.5	−87.75	83.75	6.5	89.0	105.75	84.0	K. Khudoba, 1925
1.8*	+64.3	−48.1	−77.8	−47.9	16.1	73.5	−89.9	−74.0	18.0	84.0	−88.2	84.0	6.1	90.0	106.7	84.0	O. Grosspitsch, 1908
1.9	+70.0	−48.0	−70.0	−48.0	17.25	72.75	−88.0	−72.75	17.25	88.25	—	—	—	—	—	—	V. V. Nikitin, 1926
2.4	+65.1	−48.7	−76.7	−47.9	16.25	73.2	−89.4	−74.0	17.5	84.5	−88.0	84.5	5.5	89.8	107	84.5	E. Wuelfing, 1921-1924
2.5*	+62.2	−47.5	−79.4	−47.9	15.5	73.3	−89.75	−73.2	18.6	81.1	87.7	81.8	8.8	89.75	106.5	81.1	E. Leisen, 1934
2.75	—	—	—	—	16.25	74.0	−88.5	−73.75	16.5	87.75	—	—	—	—	—	—	V. V. Nikitin, 1926
3.5	+64.75	−49.5	−78.8	−47.9	15.3	74.5	−89.1	−74.8	16.4	83.75	−87.6	84.0	6.5	89.0	105.25	83.3	F. Bekke, 1900
4.5	+64.5	−48.9	−77.5	−48.4	16.0	73.8	89.8	−74.2	17.5	84.0	−88.2	84.0	6.0	90.2	106.2	84.0	H. Bendl, 1922
7.0	+66.0	−49.0	−81.0	−48.0	14.0	76.0	−89.0	−76.0	16.0	83.0	−87.5	83.0	7.1	89.6	104	83.0	V. V. Nikitin, 1926
7.4	+66.0	−47.0	−85.2	−48.0	12.1	77.0	89.8	−78.0	16.0	80.0	−88.2	80.2	10.0	90.5	103	80.25	A. Engels, 1937
12.5	+66.5	−46.5	+86.5	+45.9	9.5	80.5	−89.5	−81.0	16.5	76.5	87.2	77.0	13.25	88.9	100	76.5	F. Bekke, 1900
13.5	+66.9	−45.6	+85.9	+47.9	9.0	81.0	89.0	−81.0	16.25	76.25	−89.0	76.5	13.5	91.2	99.5	76.3	F. Bekke, 1900
14.0	+68.0	−45.0	+84.0	+47.0	8.0	82.1	89.2	−82.0	16.0	76.0	−89.0	76.0	14.0	91.0	98	76.0	H. Tertsch, 1903
14.1	+69.25	−41.0	+79.0	−45.0	6.0	84.1	88.75	−84.0	18.5	73.5	90.0	73.25	16.75	91.5	96.25	73.25	A. Engels, 1937
(17)	+71.2	−37.3	+70.5	+42.0	2.5	89.6	87.5	−89.75	19.3	70.7	87.7	70.7	19.75	92.7	90.5	70.5	H. Tertsch, 1950
22.0	+70.4	−42.0	+69.5	+45.0	−2.0	88.0	−89.5	−89.0	21.0	69.0	88.75	69.5	20.5	91.0	89	69.5	H. Tertsch, 1950
23.5	—	—	—	—	−2.25	88.0	−89.75	—	—	—	—	—	—	—	—	—	V. V. Nikitin, 1926
24.0	+68.1	−40.1	+61.4	+42.5	−4.0	86.0	−89.0	87.0	25.5	64.75	87.3	64.6	25.5	91.4	86.5	64.75	S. Tsuboi, 1923
25.0	+70.8	−39.8	+59.3	+41.0	−6.8	83.0	−89.5	84.0	26.0	65.0	87.0	65.0	25.2	90.8	83.7	65.0	H. Tertsch, 1903
(26.5)	+75.0	−37.3	+53.7	+38.5	−13.3	76.7	−89.25	78.3	28.0	64.7	83.75	66.0	25.3	90.9	76.7	64.7	H. Tertsch, 1950
27.5	+74.5	−41.3	+55.5	+41.4	−10.6	79.4	90.0	80.5	27.0	65.0	87.75	65.5	25.0	90.0	79.4	65.0	E. Leisen, 1934
28.5	—	—	—	—	−11.0	79.0	90.0	—	—	—	—	—	—	—	—	—	V. P. Belikov, 1932
31.0	+76.8	−41.8	+48.5	+40.9	−15.5	74.5	−89.5	75.0	31.5	62.4	85.4	63.5	27.5	89.6	74.2	62.4	E. Leisen, 1934
31.0	+76.3	−41.5	+49.3	+41.7	−14.75	75.2	−89.8	75.5	30.2	62.9	85.25	63.8	27.2	89.7	75	62.9	E. Leisen, 1934
32.0*	+79.6	−37.8	+44.3	+39.1	−21.0	69.0	−89.5	72.0	34.0	62.0	79.6	64.2	28.2	90.8	69	62	E. Ernst and H. Nieland, 1934
33.0*	+81.5	−35.2	+39.9	+37.7	−25.5	64.0	−88.6	78.2	38.0	61.0	77.5	65.0	29.0	91.5	64.5	61.0	E. Ernst and H. Nieland, 1934
34.0*	+81.7	−36.4	+38.6	+37.5	−26.3	63.6	−89.0	67.5	38.5	60.4	76.2	64.4	29.8	90.9	63.4	60.4	E. Ernst and H. Nieland, 1934
35.0	+76.0	−42.0	+42.5	+39.5	−18.0	72.0	88.4	74.0	36.0	59.0	82.2	60.2	30.7	88.5	70.75	58.8	O. Grosspitsch, 1921
37.0	+80.5	−36.3	+40.0	+37.1	−25.0	65.0	90.0	69.0	38.0	60.0	77.8	63.5	30.0	91.0	65.0	60.0	S. Tsuboi, 1923
37.5*	+80.0	−42.4	+38.9	+38.2	−23.0	67.5	88.0	69.2	38.5	59.0	80.0	60.0	31.5	88.0	66.0	59.0	F. Bekke, 1921

Table 1 (continued)

% An	A		B		⊥ (010)			[001]			⊥ [001] (010)			Φ	Ψ	Θ	References
	λ	φ	λ	φ	α	β	γ	α	β	γ	α	β	γ				
38.5	+76.3	—48.0	+37.3	+41.0	—19.0	71.2	86.2	72.2	39.25	56.25	83.0	57.5	33.25	85.2	68.0	56.25	V. V. Nikitin, 1926
40.0	+80.3	—42.8	+35.5	+37.9	—24.0	66.5	87.3	69.0	41.0	57.1	79.0	59.0	33.0	86.8	64.2	57.1	F. Bekke, 1921
40.0	+80.5	—43.0	+35.5	+38.0	—24.5	66.0	88.0	—	—	—	—	—	—	—	—	—	I.D. Muir, 1955
40.0	—	—	—	—	—26.5	64.0	88.5	—	—	—	—	—	—	—	—	—	I.D. Muir, 1955
40.5	+82.9	—41.8	+29.8	+37.3	—28.25	61.75	87.0	65.2	45.0	55.4	76.3	58.5	35.0	86.9	60.6	55.4	E. Ernst and H. Nieland, 1934
44.0*	+80.5	—44.5	+30.5	+37.5	—26.0	64.0	85.0	67.0	44.75	54.25	78.25	56.0	36.0	85.0	62.0	54.25	I.D. Muir, 1955
44.0*	—	—	—	—	—29.0	61.5	86.0	—	—	—	—	—	—	—	—	—	I.D. Muir, 1955
44.0*	+82.5	—41.9	+29.7	+37.3	—29.0	61.0	87.0	65.2	45.6	54.6	76.0	57.8	36.0	86.9	60.6	54.6	E. Ernst and H. Nieland, 1934
45.5*	+83.2	—45.3	+23.3	+35.8	—30.5	60.0	84.5	64.0	50.0	50.5	75.5	54.2	39.5	83.0	55.4	51.2	E. Ernst and H. Nieland, 1934
47.0*	+80.5	—50.0	+20.0	+35.5	—29.0	62.0	82.0	65.0	54.0	46.9	76.5	48.5	44.2	78.5	53.5	46.9	I.D. Muir, 1955
47.0*	—	—	—	—	—31.5	59.5	83.5	—	—	—	—	—	—	—	—	—	I.D. Muir, 1955
47.0*	+83.5	—45.4	+21.5	+36.3	—30.9	59.6	84.9	64.0	50.4	50.0	74.0	54.0	40.0	83.3	52.9	50.4	E. Ernst and H. Nieland, 1934
49.0*	+82.4	—46.1	+19.5	+35.6	—31.5	59.0	84.5	64.0	52.5	48.5	73.5	52.5	42.5	81.8	53.8	48.5	E. Ernst and H. Nieland, 1934
51.0*	+77.0	—54.6	+14.9	+34.9	—28.5	64.3	78.6	65.2	59.2	41.5	77.2	41.5	51.2	72.5	50.5	41.5	E. Leisen, 1934
52.0*	+82.2	—49.6	+16.0	+33.8	—32.0	59.7	80.8	63.0	57.0	45.1	73.9	48.0	46.5	76.6	49.4	45.1	E. Ernst and H. Nieland, 1934
52.0*	+82.6	—49.6	+14.0	+32.9	—33.5	58.8	79.8	62.0	59.0	44.2	74.1	47.0	47.2	75.5	47.7	44.2	E. Ernst and H. Nieland, 1934
52.0*	+78.5	—54.0	+14.0	+33.0	—30.5	62.5	77.5	63.0	60.2	42.0	76.0	42.5	51.0	71.2	47.8	41.0	I.D. Muir, 1955
52.0*	—	—	—	—	—32.0	60.0	79.0	—	—	—	—	—	—	—	—	—	I.D. Muir, 1955
52.0	+77.5	—55.5	+16.5	+35.0	—27.8	65.75	77.4	65.0	58.4	42.5	78.75	42.1	50.0	71.8	51.0	41.8	V.I. Luchitskiy, 1905
54.0	+74.5	—54.8	+13.0	+27.5	—30.2	63.8	75.7	63.5	63.7	39.5	76.7	36.75	54.2	68.0	44.5	40.0	A. Engels, 1937
56.0*	+75.0	—57.0	+ 8.0	+28.0	—31.5	64.5	73.0	62.0	70.0	36.3	74.5	35.0	59.2	60.5	37.0	36.3	I.D. Muir, 1955
56.0*	—	—	—	—	—33.0	61.5	74.5	—	—	—	—	—	—	—	—	—	I.D. Muir, 1955
54.0	+74.8	—56.6	+14.6	+33.0	—28.2	66.0	76.0	64.1	61.0	39.8	78.5	39.0	53.0	68.8	48.2	39.8	O. Grosspitsch, 1914
57.5	+80.1	—53.5	+ 9.8	+30.1	—33.8	60.0	76.0	61.5	65.0	39.8	73.6	41.0	54.0	67.4	41.3	39.8	E. Ernst and H. Nieland, 1934
58.0	+74.0	—57.2	+10.0	+28.5	—30.5	65.0	73.0	62.5	68.0	36.5	76.5	35.2	58.0	61.5	39.5	36.5	V. V. Nikitin, 1926
60.0	+78.0	—54.3	+ 7.8	+27.9	—34.7	60.0	73.2	60.8	68.0	37.9	73.0	38.5	57.0	63.7	37.6	37.9	E. Ernst and H. Nieland, 1934

*Plagioclases whose composition has been determined by the equation for the intermediate light refraction on the basis of the cited values of γ, β and α.
The composition of two roasted specimens, determined before roasting by A. Koehler's "low-temperature" curve, is shown in parentheses.

form — carnegieite. For the feldspars with the carnegieite "molecule", the name "anemousite" was proposed.

In 1934 these plagioclases were repeatedly and very thoroughly studied by E. Ernst and H. Nieland [13]. Their investigations were concerned with the problem of anemousite only to the extent of showing that the chemical anomalies and the variations in the optical properties did not exceed the limits normally observed among the plagioclases. The crystals selected for study were not so large that the chemical analyses and the optical measurements could be made on the same material. For this reason the following method was adopted. On the one hand, in the case of four specimens the chemical composition and only one property — the specific weight — were carefully determined. On the other hand, for a greater number of specimens, including the 12 used by us, the optical orientation, the light refraction and the specific weight were determined. Thus the authors could draw some conclusion regarding the composition of the latter specimens by comparing their specific weights with those of the four chemically analyzed specimens, without using any of the curves for the determination of the normal plagioclases.

After E. Ernst and H. Nieland had shown that the Linosa plagioclases did not represent a special variety — "anemousite" — their data were used for other purposes. A. Koehler [14] constructed a curve for the "high-temperature" plagioclases of intermediate composition on the basis of the data on the optical orientations of these same Linosa plagioclases. In this case their composition was indicated by the magnitude of their specific weight, as on the tables by E. Ernst and H. Nieland. These data were transferred in similar form to all the later diagrams with "high-temperature" curves, including the recent ones by K. Burry [12].

In addition, the refractive indices, which have been measured with greater precision (±0.0005) and are more reliable because for certain of the same specimens repeated measurements were made by E. Leisen (see 12), indicate a somewhat different composition. The calculation of the percentage content of anorthite, made by the formula for the average light refraction as computed by us [6], has shown that the composition as determined in this manner coincides with the composition determined by the specific weight for the middle part of the series of specimens studied (preparations 5' - 9'), but shows higher values for the acidic part of the series and lower for the basic — that is, the specific weight curve that was used should be somewhat more gently sloping. This difference is most important in the case of the basic part of the series where it becomes as great as 4 to 6 numbers. It should be remarked that for the latter specimens (preparations 11' - 13') the specific weight was not determined, but was calculated from the d-β curve constructed by the authors from the measurements of β and d for the remaining samples of this series. Moreover these show that "the specific weight of preparations 12' and 13' is somewhat unreliable, as a result of the great degree of extrapolation".

For these reasons the composition of all the specimens of E. Ernst and H. Nieland was determined by the average light refraction as calculated by the cited values of α, β and γ, using the empirical formula $\%\,An = 1960.78.\ N_{av} - 3004.31$.

Measurements of the refractive indices have also been used as the basis of the composition of the plagioclases described by I. D. Muir [9], since the plagioclase number, as determined by chemical analysis, clearly does not correspond to the indicated optical orientation. This is explained, apparently, by the difficulty of obtaining identical material for measurement for chemical analysis from the rocks described by him.

2. Data obtained by the Present Author

V.V. Nikitin, lacking information on the relationship between the optical properties of the plagioclases and their origin, but assuming that such a relationship must exist, instead of selecting large crystals suitable for both measurement and analysis turned to the plagioclases of typical intrusive rocks, which must serve as the basis for constructing curves for the plagioclases of intrusive rocks. The curves for determining "high-temperature" plagioclases were constructed by A. Koehler from the data on the plagioclases of the extrusive rocks of Lake Linoza.

The difficulty of separating homogeneous crystals from the rocks, the zonality normal in plagioclases from extrusive rocks and the unreliability that always exists in these cases in the relationship of the chemical analyses to the constants measured on any particular twin compelled E. Ernst and H. Nieland to disregard the direct comparison of the results of chemical analysis with the measurements of the optical orientation. The example of the lack of success of such comparison in the thorough and careful investigation by I. D. Muir also shows the inadequate reliability (with rare exceptions) of the data thus obtained for plagioclases taken from intrusive or extrusive rocks. Another means was thus chosen of obtaining additional data for the preparation of the diagrams.

From the conceptions of the relationship of the optical orientation of the plagioclases to their composition and degree of successiveness it follows that on the stereogram the orientation of the plagioclases of a given composition should

be shown not by a point but by a line — the "line of equal composition" — along which will be located the points corresponding to the plagioclases of this constant composition but with different degrees of successiveness.

Structures with different degrees of successiveness may be obtained by roasting at different temperatures or for different lengths of time. The time that can be used under laboratory conditions will produce only varying successiveness — a gradation from the original value of the degree of successiveness to a state ("high-temperature") characterized by lack of successiveness.

Thus the lines of equal composition can be drawn along the points obtained by measuring specimens of the same composition roasted under different conditions. The following specimens were chosen for this purpose:

		Plagioclase number
I.	Albite, Lower Tagil district, Chernoistochinskoye village	1.5
II.	Albite from mariupolite in the October massif	(~2.5)
III.	Oligoclase, Chupa	16
IV.	Oligoclase, Chupa	18.5
V.	Oligoclase, Slyudyanka	24
VI.	Andesine, Archean gneisses of Mama	40
VII.	Andesine, Korosten'skiy massif	48
VIII.	Labradorite, Korosten'skiy massif	54
IX.	Labradorite, Korostan'skiy massif	60

(The plagioclase number refers to the percentage content of the anorthite component: $\frac{An}{An + Ab + Or}$)

The composition of the plagioclases was determined by the refractive index of a glass obtained in the oxidizing flame from a melt of the crystals used in the roasting (except for the albite from the mariupolite, whose composition was not used in the calibration and was determined by the orientation of the indices).

The samples were prepared as follows. A block crystal (usually a triad of albite Carlsbad twins, more rarely only albite twins, frequently in combination with pericline twins) was cleaved across the [100] axis into two or three, and sometimes up to six, pieces. From one of the fragments a thin section was prepared, from which the optical orientation was measured. The others were polished down to plates some 1.5 — 3 mm thick. These plates were roasted and thin sections were then prepared from them as well. The optical orientation was measured on the Fedorov stage, partly in a Na light.

The roasting was done in a silite pipe furnace at a temperature of 1060° ± 40°, measured with a platinum thermocouple. The continuous roasting was carried on for periods from 12 hours to 12.5 days (300 hours).

At the roasting temperature (1060°) the tiny inclusions of ilmenite in the plagioclases of the Korostenka massif were not altered, and there was almost no change in the color of the specimen. Only at a temperature of about 1300° (in preliminary tests) did these inclusions disappear, and at that temperature the sample took on a grayish-white color and a porcelain-like appearance with cinnamon-brown flow structures and pores. Moreover the samples fused at the edges and along fractures, and the melt upon slow cooling was partially crystallized, forming an "andesite" structure.

Of the large number of roasted and measured samples, 28 were selected as yielding the most reliable data. The results of the measurements are given on Table 2. Measurements of the optical orientation of the plagioclases before and after roasting were also made earlier and partly used by us, but there appeared to be a displacement, during the roasting, of some one of the crystallographic directions, usually $\perp$(010). For the majority of specimens Table 2 shows the complete orientation before and after roasting.

The kinetics of the breaking of the successiveness of the plagioclases as a result of roasting at temperatures exceeding that at which the successiveness began to be lost or at temperatures close to it, depend on the composition. The time of the loss of successiveness in the basic plagioclases was measured in tens of minutes, in the intermediate plagioclases in tens of hours, and in the acidic plagioclases in days or tens of days. Therefore series of points corresponding to the various lengths of roasting were obtained only for the andesites and labradorites.

The andesite and labradorite specimens from the Korostenka massif showed considerable fluctuations in composition, within the large (from 2 to 15 cm) block crystals. For this reason, in the case of all the fragments of a single such block crystal there was a control of the uniformity of their composition, and the final tables show only the fragments of the same composition. For this purpose, after the roasting and measurement on the Fedorov stage part of the crystal was removed from the thin section and attempts were made to produce a glass (in the oxidizing flame), whereupon the refractive index of the glass was measured. This could be done for a few of the samples. For the others, the refractive indices of the crystals removed from the thin sections were measured. The refractive indices are related to the structurally less sensitive constants, and in the case of the

Table 2

Optical Orientations of Plagioclases before and after Roasting at 1060° C

Specimen No.	% An	Roasting time (hours)	A		B		⊥ (010)			[001]			⊥ [001] ∥ [001]			Φ	Ψ	Θ
			λ	φ	λ	φ	α	β	γ	α	β	γ	α	β	γ			
I	1.5	—	+68.3	−38.8	−76.5	−35.5	18.0	72.0	89.0	72.2	19.0	84.5	−87.0	84.8	6.0	89.0	108.0	84.0
I	1.5	102	+62.5	−37.0	−85.2	−43.0	18.2	72.0	−87.0	72.0	22.0	78.0	−88.5	77.5	12.5	93.0	108.0	78.0
II	2.5	—	+70.0	−37.0	−82.0	−35.7	17.2	72.8	89.5	73.0	18.0	84.4	−88.0	84.8	5.6	89.5	107.0	84.0
II	2.5	308	+66.5	−39.5	−82.2	−42.8	16.6	73.5	−88.5	73.5	18.5	82.0	−89.0	82.0	8.0	92.0	107.0	82.0
II	2.5	308	+67.0	−18.7	+79.0	+29.3	13.8	77.0	−85.5	76.5	22.0	73.0	89.5	72.0	18.0	95.0	104.0	73.0
III	16	—	+68.0	−44.8	+80.3	+46.8	5.5	85.0	−88.5	84.3	16.5	74.3	−89.5	74.5	15.5	91.0	96.0	74.5
III	16	256	+70.0	−33.5	+68.0	+40.0	3.5	88.5	−87.0	90.0	21.0	69.0	86.0	69.5	21.0	93.5	90.0	69.0
IV	18	150	+70.0	−29.0	+64.4	+38.0	6.0	86.0	−85.5	88.4	21.0	69.0	84.2	69.2	21.8	95.0	88.5	69.0
V	24	—	+73.0	−40.8	+63.0	+41.0	5.8	84.5	89.5	85.2	23.5	66.5	86.5	67.0	23.2	90.5	85.0	66.5
V	24	308	+74.5	−26.5	+55.8	+36.8	16.0	74.5	86.0	78.5	27.0	66.0	79.2	68.0	25.0	95.0	77.0	66.0
VI	40	—	+78.0	−51.8	+32.5	+41.0	20.8	70.2	84.6	71.0	44.0	52.0	82.2	53.0	38.0	83.0	66.0	53.0
VI	40	194	+80.0	−43.0	+30.0	+37.0	27.0	63.0	87.5	67.0	44.0	55.0	76.8	58.2	35.0	87.0	61.5	54.5
VII	48	—	+79.5	−55.0	+19.0	+39.8	25.5	66.5	80.0	67.0	53.5	45.5	79.0	45.5	46.5	77.5	57.0	45.5
VII	48	12	—	—	—	—	28.0	64.0	81.0	—	—	—	—	—	—	—	—	—
VII	48	24	+78.0	−48.7	+18.0	+34.0	29.5	62.0	81.5	64.0	54.0	47.0	75.7	49.2	44.5	78.0	53.5	47.0
VII	48	38	—	—	—	—	29.0	63.0	80.8	—	—	—	—	—	—	—	—	—
VII	48	48	+80.0	−47.0	+16.0	+34.6	31.5	59.5	82.5	63.0	54.0	48.0	74.0	54.0	43.5	80.0	52.5	48.0
VII	48	72	—	—	—	—	31.0	60.0	82.5	—	—	—	—	—	—	—	—	—
VIII	54	—	+77.5	−57.8	+12.5	+32.2	29.0	66.0	75.0	64.0	63.0	39.2	78.0	38.0	55.0	66.0	46.0	39.0
VIII	54	24	+76.0	−52.7	+12.2	+30.0	32.0	62.0	76.3	62.2	65.0	39.0	76.0	40.0	53.5	68.0	43.5	39.5
VIII	54	36	+76.0	−53.3	+10.2	+31.5	32.0	61.5	76.5	62.5	63.0	40.5	75.5	41.0	52.5	69.0	42.5	39.5
VIII	54	72	—	—	—	—	33.6	60.0	77.2	—	—	—	—	—	—	—	—	—
IX	60	—	+67.0	−57.0	+10.0	+25.0	31.6	64.8	72.3	63.0	70.0	35.0	75.6	33.2	60.7	58.0	36.3	35.0
IX	60	24	+72.0	−54.2	+10.0	+26.0	33.5	62.5	72.5	61.0	68.5	37.5	74.5	37.0	58.0	60.5	36.3	38.0
IX	60	36	+72.0	−55.0	+ 8.0	+26.5	33.0	63.0	72.5	61.8	69.5	36.0	74.0	35.5	59.5	61.0	36.0	36.0
IX	60	72	+75.0	−55.2	+ 8.3	+26.5	34.0	62.0	72.5	61.0	69.0	37.0	74.0	37.0	58.0	61.5	37.0	37.0
IX	60	152	+72.0	−52.5	+ 8.2	+25.5	34.5	61.5	73.0	61.2	69.0	37.5	74.0	37.2	57.6	62.0	36.0	37.5

andesine labradorites their change in the loss of successiveness may be disregarded.

The refractive indices were measured by the chromatic variation method, with an accuracy of about ±0.001.

Thus the diagrams can be based on the data on the optical orientation of 71 plagioclases with known composition, of which the data were obtained from sources in the literature for 48 samples and from experiments by the present writer for 23 samples.

II. METHODOLOGY

1. Selection of the Method of Depicting the Optical Orientation

The optical orientations of the plagioclases are plotted:

1) on graphs with the coordinate axes representing composition and properties; the properties are taken to be the angles of extinction and the angles between the single axes of the indices and the optical axes in twins (according to F. Bekke and A. Koehler), or the Eyler angles (according to K. Burry);

2) on graphs in which both coordinate axes represent properties: the angles between the twinning axis and the various axes of the indices, or else the angles between the axes of the indices and the various crystallographic lines. The graphs of this type (proposed by Ye. S. Fedorov) include those of V. V. Nikitin and M. Reingard. The composition in these cases is indicated by direct calibration of the curves.

To take account of the successiveness, on both graphs one must construct not one curve, but a series of curves showing the relationship to the composition for various degrees of successiveness. Here the graphs of the first type will not yield uniform solutions. Only if the degree of successiveness is known can one determine the composition therefrom; on the other hand, when the composition is known one can determine the degree of successiveness.

Diagrams of the second type will produce a single definitive solution: the points expressing the orientation of the indices will mark the change in this orientation in relation to both the composition and the degree of successiveness. In this case the orientation is expressed as: a) a projection of the axis of the index relative to the crystallographic line (most suitably relative to the axes of the triad ⊥(010), [001] and ⊥[001]‖(010), and b) a projection of the crystallographic line (the line normal to the plane of cleavage and the twinning axis) relative to the axis of the index.

Projections of the first type are suitable for a graphic or analytical (using F. Bekke's λ and φ coordinates for the A and B optical axes, or the Eyler angles) computation of the angles between the axes of the indices and any crystallographic lines. But in this case one must use direct data obtained only by F. Bekke's conoscopic method. Data obtained by the Fedorov method must be recomputed. In addition, the α and γ curves for the "high-temperature" and "low-temperature" forms are very close to each other, and in places coincide or intersect.

Projections of the second type are best suited for use with the Fedorov method, since here one can use the data obtained directly by measurement. The curves of the most common twinning laws, over much of their extent, are quite far apart from each other for the "high-temperature" and "low-temperature" varieties. The only defect is that the angles between any particular crystallographic lines and the index axes do not give the full optical orientation. One must have the angles for at least two such lines, so that the angle between the latter will correspond to the actual angle (for example, the angle between ⊥(010) and [001] would be a right angle).

Diagrams of the second type for both kinds may be constructed in the form of stereograms, in which any axis will serve as a control for the data obtained by the two other axes, or in the case of rectangular coordinates after checking the data on the stereogram, or by computation.

Thus to express the relationship of the optical orientation to the composition and the degree of successiveness of the plagioclase, the most suitable for our purposes is a diagram of the canonical type, which shows the positions of the crystallographic lines relative to the axes of the indices.

2. Method of Treating the Material

In preparing diagrams of the optical orientation, one is faced with three tasks: 1) the construction of curves showing the change in the orientation as a function of the composition; 2) the calibration of these curves — that is, their division into units of ten per cent content of the anorthite component; and 3) the tying in of the above with the curves for various twinning laws.

On the diagram by F. Bekke, E. Wuelfing, M. Reyngard and others, the points indicating the orientation of a small number of analyzed plagioclases are connected by a smooth line. Determination of the plagioclase No. at each measurement is done by interpolation between the points corresponding to the analyzed plagioclases.

The team of authors under the direction of

V.V. Nikitin has done a great deal of work in obtaining averaged curves by means of statistical treatment of a great number of measurements made on plagioclases that were not analyzed chemically. As long as the reason for the dispersion of the points indicating the orientation was not known, this was a permissible method. At the present time, however, it is clear that this method of drawing the curves has no advantages, from the viewpoint of accuracy, over the method of drawing an average curve through several points obtained from typical and thoroughly studied specimens. (V.V. Nikitin's calibration specimens show almost no deviation from the curves obtained by statistical treatment). It is also not clear what the relationships are between the various curves and the actual crystallographic relationships, if this is not the result of chance deviations in the construction of each separate averaged curve. The curves in V.V. Nikitin's diagram were calibrated by means of a small number of chemically and optically analyzed samples; the curves are divided into units of ten per cent content of An by means of interpolation.

The curves showing the relationship between the orientation and the composition should also be lines connecting the points representing some definite degree of successiveness. To the extent that this magnitude is not determined, it is obvious that the curves in all the proposed diagrams will be in some measure arbitrary. "Average" curves may be drawn only for plagioclases of specific determined genetic types, and even these will be somewhat tentative. This is the reason for V.N. Lodochnikov's remark [3] that "each new author proposes somewhat different curves".

New prerequisites have made it necessary to pose the problem of treating the data in a different manner. The positions of the crystallographic lines of the plagioclases relative to the index axes on the stereogram must be shown not by curves, but by "divariant fields", each point of which will be determined by two variables — the composition and the degree of successiveness. The fields are calibrated by a net of curves, of which one system consists of lines connecting points of equal composition and the other system of lines connecting points of the same degree of successiveness. The former may be constructed by simple interpolation, as the contour lines are drawn on topographic maps. Their position will depend only on the accuracy of the measurement and of the chemical analysis. To construct the lines marking equal degrees of successiveness one may take the extreme values on the lines of equal composition, as obtained by measuring natural "low-temperature" (essentially successive) and natural and roasted "high-temperature" (non-successive) plagioclases. By interpolation one obtains the following lines of equal degree of successiveness: 0.0 (fully non-successive state), 0.25, 0.50, 0.75 and 1.0 (fully successive state). It is understood that the degree of successiveness here, in the physical sense, is a completely tentative magnitude.

The networks of calibrated curves for the various crystallographic lines must be tied in with each other, taking account of the following two circumstances.

1. The points of intersection of the lines of equal composition and degree of successiveness for the albite, Carlsbad and the albite-Carlsbad twin laws, corresponding to the same composition and successiveness, must be 90° apart from each other. This requirement was set earlier, in constructing the curves for the optical orientation. In that case, however, it was sufficient to tie in several calibrated points on the averaged curves (V.V. Nikitin) or to draw the curves directly through the known control specimens, whose constants were tied in with the crystallographic lines (M. Reyngard) without interpolation of the curves for the ten per cent unit contents of anorthite.

By drawing lines of equal composition through the points of 2% unit contents of An and lines of equal degree of successiveness through the points representing 0.25 unit increments, for a number of compositions from No. 0 to No. 60, we obtain up to 150 points for each twinning law for which a tie-in is to be made.

In a recently published paper by K. Burry [12] the problem of representing the optical orientations of the indices was reduced to a problem in analytical geometry of the mutual disposition of two rectilinear systems of coordinate axes with a common origin, a problem solved by Eyler. K. Burry suggested expressing the orientations of the index axes relative to three mutually perpendicular crystallographic lines, using the three angles Φ, Ψ and Θ (the "Eyler angles"). These angles were used by him to calibrate the averaged curves — "low-temperature" and "high-temperature" — by ten per cent unit contents of anorthite. For this purpose, on the "composition vs Eyler angles" diagrams were plotted the values of these angles for the analyzed plagioclases, divided into "high-temperature" and "low-temperature" varieties. About two average curves where drawn for each angle through the points obtained. Calibration of the three curves which are independent of each other, produced a calibration of the complete position of the index.

Figure 1 shows some "composition — Eyler angles" diagrams for the sepcimens indicated in Tables 1 and 2. These differ noticeably from the diagrams prepared by K. Burry (in having the composition of 12 Linoza plagioclases and in the presence of some additional data).

The curves have been drawn through the

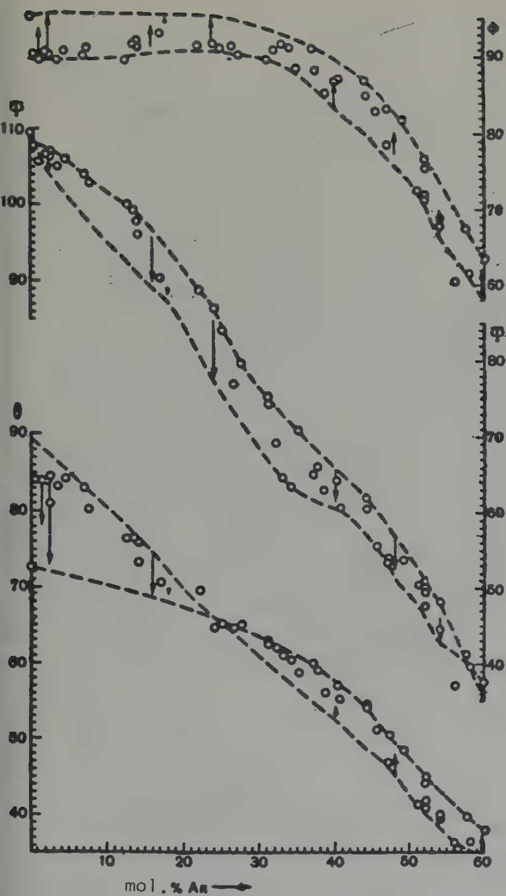

FIGURE 1. Diagram of Eyler angles, based on data in Tables 1 and 2.

extreme — "low-temperature" and "high-temperature" — values of the angles. The field between them was interpolated in the manner described above. From the appropriate points, the positions of ⊥(010), [001] and [001] ∥ (010) relative to the index angles were calculated analytically; for this purpose some 1,200 equations were worked out.

Through the resulting 150 points, which were tied in with each other, for each of these crystallographic lines the lines of equal composition and degree of successiveness were also plotted.

2. There is also another requirement for the curves of the various twinning laws, however, which was not made earlier. The three Eyler angles are independent of each other only mathematically; physically they may be real and non-real combinations of these angles. Not all sets of three points ⊥(010), [001] and [001]∥(010), separated by 90° from each other, correspond to the same single composition and degree of successiveness. Hence, according to our axiomatic presuppositions, each plagioclase of a specific composition and degree of successiveness has a single optical orientation, any point on ⊥(010) or some other crystallographic line will fully define both variables characterizing the plagioclase, for which there will be corresponding single values of [001], ⊥[001]∥(010), etc. Thence it follows that the respective points separated by 90° on the networks of curves should, in reality, correspond to the same values.

This condition, however, is achieved only if the Eyler angle curves are plotted in such a manner as to have the same sign. On Figure 1 the extreme curves have been drawn as much as possible through the known control points corresponding to the same plagioclase on the diagrams of all three angles. Specimens of the transitional type in general occupy approximately the same intermediate position on these diagrams. This indicates that there is generally a regular and uniform change in the angles Φ, Ψ and Θ in the succession, and permits the assumption that for each intermediate value of any Eyler angle there is a similar intermediate position of the two other angles.

On K. Burry's averaged curves the transitional plagioclases do not occupy corresponding uniform positions. This he explained by an irregular change in the Eyler angles.

An irregular change in these angles, however, corresponds to a torsion of the index along a complex trajectory formed by the lines of equal composition in the form of curves. A uniform change corresponds to a displacement of the index in one direction: in this case, the lines of equal composition should be straight lines. The latter corresponds more closely to a disposition of the points on the ⊥(010) fields with the greatest number of points (Figure 2), as well as on the fields of the other crystallographic lines.

THE DIAGRAM OF THE COMPOSITION — DEGREE OF SUCCESSIVENESS — OPTICAL ORIENTATION OF ACIDIC AND INTERMEDIATE PLAGIOCLASES (FIGURE 3)

The solid curves (arrows) on the diagram are the lines of equal composition. The hatched lines show the approximate positions of the lines connecting points of the same degree of successiveness. The numbers around the curves are the plagioclase numbers (per centage contents of the anorthite component) and the tentative degrees of successiveness: 0.0 — total lack of succession; 1.0 — fully successive state. The plagioclase is defined by the two magnitudes:

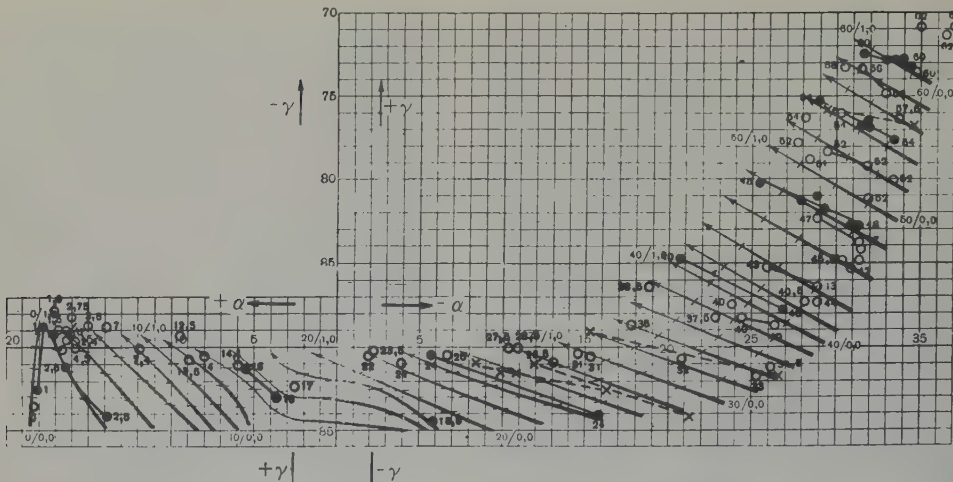

FIGURE 2. Blue: position of ⊥ (010) relative to axis of optical indicatrix. Black: position of ⊥ (010) according to data in Table 1 (circles) and Table 2 (solid black circles joined by straight lines). Rectilinear coordinates: right, upper hemisphere projection; left, lower hemisphere projection (negative values of angles between β and ⊥ (010) respectively change the signs of the α and γ axes); the curvatures of the lines indicating equal composition (arrows) at the intersections of the coordinate axes are the result of the transfer from a stereographic projection to a projection with a rectilinear system of coordinates; the figures at the ends of the composition lines are: first, the plagioclase number, and second, the conditional degree of regulation (1.0 - fully regulated, 0.0 - completely unregulated). The crosses indicate the data from Scholler (see 12 in list of references).

for example, 25/0.50 indicates an intermediate oligoclase with 25% of the anorthite component and a degree of successiveness equal to 0.50

The lines of equal composition have been drawn by units of 2% of the anorthite component, except for the compositions of No. 10 - 20 for the Carlsbad and No. 0 - 20 for the albite-Carlsbad laws, where these lines have been plotted by units of 10% anorthite, owing to the crowding of the curves and their numerous intersections.

V.V. Nikitin's diagram shows curves for a large number of crystallographic lines. But only some of these, which may be established with fair accuracy, are significant in defining the composition and the degree of successiveness. These are the cleavage along (001) and (010), and the twinning axes of the most common twinning laws: ⊥(010), [001], ⊥[001]||(010), as well as [010], [100] and ⊥[100]||(010).

Twins following the other laws are rare, and for a special study of these complex regular intergrowths it is more convenient to use the triad method and the L.A. Vardanyants diagram.

The ⊥(130), ($\bar{1}30$), (100), (101), ($\bar{1}01$), ($\bar{1}11$), ($\bar{1}1\bar{1}$) and others, which merely unnecessarily complicate the diagram, are of no significance in defining the plagioclase. The diagrams in Figure 3 thus show only the most common and reliably established lines: ⊥(010), [001] and ⊥[001]|| (010).

A CHECK OF THE OPTICAL ORIENTATION DIAGRAMS

The logical purpose of each diagram is to determine the significance of the results of measurements on the basis of measurements made earlier — that is, to construct a curve or net of curves through particular reference points.

If the measurements and the chemical analyses were made with absolute accuracy, and if the material used in the chemical analyses were the same as that on which the measurements had been made, the reference points would be regularly arranged and each of them, in defining a plagioclase by the net of curves constructed, would correspond to the composition of a given specimen. The lack of such accuracy is the reason for the averaging. In the general case, the points whose compositions form the basis for constructing the diagram may acquire a new value which should not exceed the errors in measurement and determination of the composition. This characterizes the reliability of the treatment of the raw data.

The compositions of the plagioclases whose constants are given in Tables 1 and 2 were determined from the nets of curves in Figure 1. The greatest deviation of the plagioclase number determined in this manner from that established by chemical analysis or measurement of the refractive indices, in only six determinations from any one net of curves out of 72 determinations from all the nets of curves, is 2% anorthite. In the remaining cases the deviations are no greater than 0.5 - 1.0% An. This

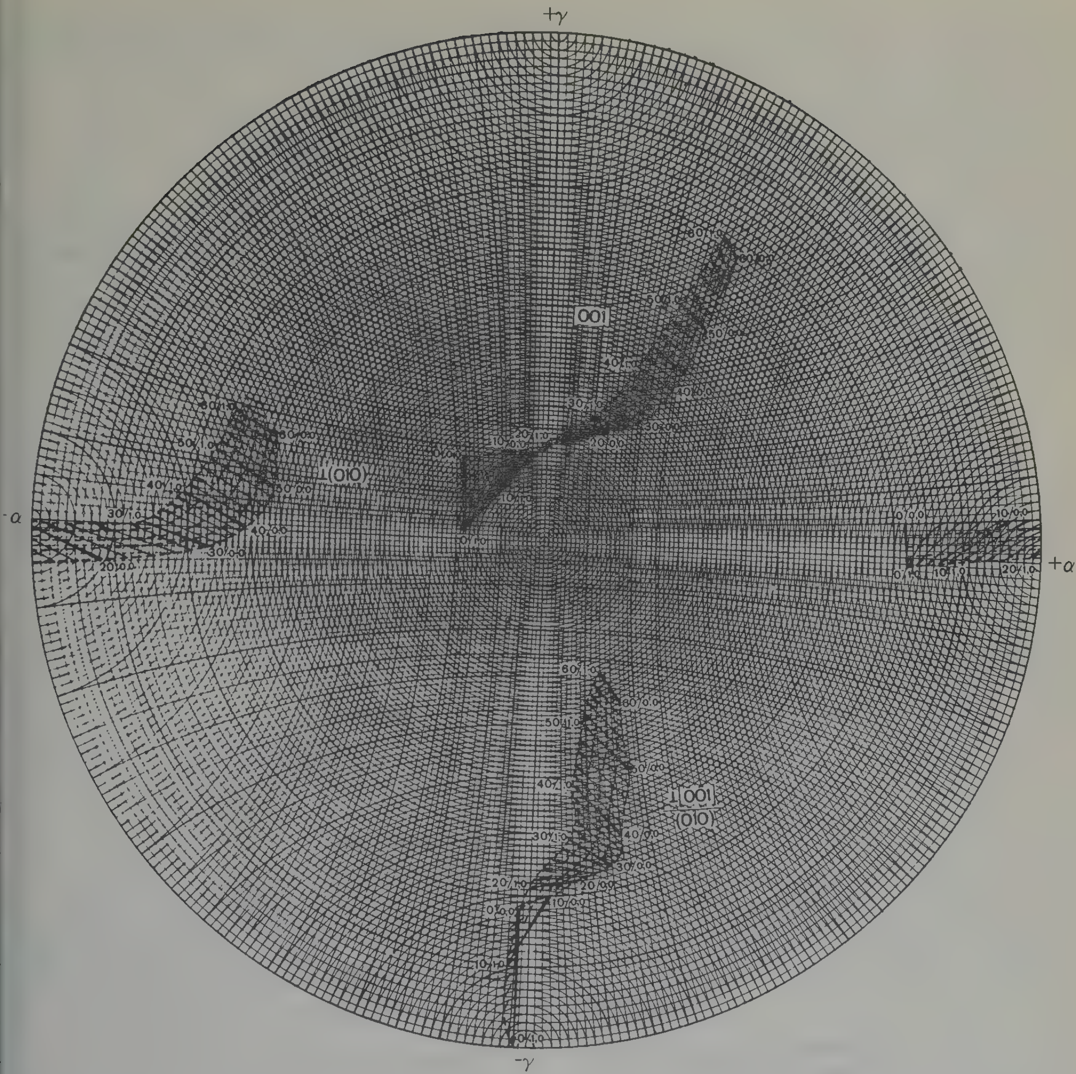

FIGURE 3. "Composition - degree of regulation - optical orientation" diagram for acidic and intermediate plagioclases (A.S. Marfunin, 1957).

characterizes the accuracy to which the lines of equal composition have been drawn.

The coincidence of the composition and degree of successiveness as determined from various nets of curves, and their identical deviations from specimens of given composition, indicate that the respective points on these nets have been properly located, so that the cause of the discrepancy is to be sought either in errors in determining the composition of the specimen or in the inexact number of the calibrated curve.

The discrepancy in the composition and the degree of successiveness determined by various curves (according to Tables 1 and 2) amounts to 2% anorthite in eight cases and to 0.25 successiveness in five cases. For the rest, it is no more than 1% and 0.5 respectively. These discrepancies may be due to lack of accuracy in selecting the appropriate points or in determining the optical orientation (non-real combinations of Φ, Ψ and Θ, or differing values of the orientations of various crystallographic lines).

Each precise measurement of the orientation of two crystallographic lines on a single crystal is a check of the accuracy in the selection of the corresponding points, and in the construction of the calibrated curves.

These remarks are made only in regard to the accuracy of the treatment of the raw data. The data forming the basis for the diagrams are still incomplete, and contain a number of contradictions. This is true especially of the "high-temperature" plagioclases. The fact that the ternary diagram in Figure 3 is based on data obtained for the most part before the relationship between the optical properties and the degree of successiveness became known indicates the objective nature of the general direction of the curves in it, but also shows the incompleteness of the data and the smaller absolute accuracy of the diagram.

CONCLUSION

The diagram of the optical orientations of acidic and intermediate plagioclases (Figure 3) has been founded on the assumption of a relationship between the optical properties of the plagioclases and their composition and degree of successiveness. The data were obtained from those in the literature, and those obtained additionally by experiments in roasting, encompassing the complete optical orientation of 71 plagioclases. The positions of the twinning axes of the albite, Carlsbad and albite-Carlsbad laws relative to the index axes have been shown not by curves, but by fields calibrated by lines connecting points of equal composition and degree of successiveness. These networks of lines have been tied in with each other and calibrated by the Eyler angles in such a manner that the distance between the respective points on the fields of the above-mentioned twinning laws is 90°, and their combinations are real combinations. The tentative degree of successiveness has been determined in addition to the composition.

The diagram is suitable for determination of plagioclases of any genetic type, and is universal in the sense that it does not require a choice as to whether to use the "low-temperature" or "high-temperature" curve, inasmuch as the pole of the face or axis in any case falls upon the point where the composition line intersects the line for the degree of successiveness.

On the diagrams of the "monovariant" type (where the orientation is expressed as a curve) the points off the curve follow the line perpendicular to the nearest curve ("high-temperature" or "low-temperature"). Since they are not perpendicular throughout the entire extent of the composition line, there will be some error in determining the composition. This error is eliminated in the diagram proposed by the author of the present article.

The networks of curves for the different twinning laws are rigidly interrelated. For this reason, in a determination of all the constants that express the optical orientation of a plagioclase, it is sufficient to make a single determination from the net of curves for any given twinning law.

REFERENCES

1. Zavaritskiy, A.N., V.S. Sobolev, L.G. Kvasha, V.P. Kostyuk and A.P. Bobriyevich, Novyye diagrammy dlya opredeleniya sostava vysokotemperaturnykh plagioklasov. [NEW DIAGRAMS FOR DETERMINING THE COMPOSITION OF HIGH-TEMPERATURE PLAGIOCLASES]: Zap. Vses. mineralog. o-va, ch. 87, vyp. 5, 1958.

2. Lebedev, A.P., Plagioklazy chetvertichnykh lav Alageza. [THE PLAGIOCLASES IN THE QUATERNARY LAVAS OF ALAGEZ]: Tr. In-ta geol. nauk Akad. Nauk SSSR, vyp. 5, petrogr. ser., no. 4, 1938.

3. Lodochnikov, V.N., Glavneyshiye porodoobrazuyushchiye mineraly. [THE PRINCIPAL ROCK-FORMING MINERALS]: Gosgeoltekhizdat, 1955.

4. Marfunin, A.S., O petrograficheskom znachenii strukturnykh prevrashcheniy v polevykh shpatakh. [THE PETROGRAPHIC SIGNIFICANCE OF STRUCTURAL TRANSFORMATIONS IN FELSPARS]: Sov. geologiya, sb. 51, 1956.

5. Marfunin, A.S., Novaya diagramma opticheskoy orientirovki kislykh i srednykh plagioklasov. [A NEW DISGRAM OF THE OPTICAL ORIENTATION OF ACIDIC AND INTERMEDIATE PLAGIOCLASES]: Dokl. Akad. Nauk SSSR, t. 118, No. 6, 1958.

6. Marfunin, A.S., Empiricheskoye uravneniye zavisimosti srednego svetoprelomleniya plagioklazov ot sostava. [AN EMPIRICAL EQUATION EXPRESSING THE RELATIONSHIP BETWEEN THE AVERAGE LIGHT REFRACTION AND THE COMPOSITION OF PLAGIOCLASES]: Zap. Vses. mineralog. o-va, ch. 88, vyp. 3, 1959.

7. Nikitin, V.V., Novvyye diagrammy dlya opredeleniya polevykh shpatov universal'nym metodom Fedorova. [NEW DIAGRAMS FOR DETERMINING THE FELDSPARS BY THE FEDOROV UNIVERSAL STAGE METHOD]: Zap. Ros. Mineralog. o-va, ch. 55, vyp. 1 - 2, 1926.

8. Nikitin, V.V., (Ispravleniye i dopolneniye diagrammy dlya opredeleniya polevykh shpatov Fedorovskim metodom). [(CORRECTIONS AND ADDITIONS TO THE DIAGRAM FOR DETERMINING FELDSPARS BY THE FEDOROV METHOD)]: Miner.-Petr. Mitteil., Bd. 44, H. 2-3, 1933.

9. Polevyye shpaty. [FELDSPARS]: Sb., t. 2, Izd-vo in. lit., 1956.

10. Sobolev, V. S., Vvedeniye v mineralogiyu silikatov. [INTRODUCTION TO THE MINERALOGY OF THE SILICATES]: Izd-vo L'vovsk. Un-ta, 1949.

11. Sobolev, V. S., Fedorovskiy method. [THE FEDOROV METHOD]: Gosgeoltekhizdat, 1954.

12. Burri, C., Charakterisierung der Plagioklasoptik durch drei Winkel und Neuentwurf des Stereogramms der optischen Orientierung für konstante Anorthit-Intervalle. Schweiz. mineral und petrogr. Mitt., Bd. 36, H. 2, 1956. (A complete list of references assembled according to the optics of feldspars.)

13. Ernst, E., Nieland H. Plagioklase von Linosa, ein Beitrag qur Anemousitfrage. Tschermaks mineral. und petrogr. Mitt., Bd. 46, H. 2–3, 1934.

14. Köhler, A., Die Abhängigkeit der Plagioklasoptik vom vorausgegangenen Wärmeverhalten. Tschermaks mineral. und petrogr. Mitt., Bd. 53, H. 1, 1941.

15. Schuster, M., Über die optische Orientierung der Plagioklase. Tschermaks mineral. und petrogr. Mitt., vol. 3, 1888.

16. Tschermak, G., Chemish-mineralogische studie. 1. Die Feldspathgruppe. Stb. Akad. Miss. Wien, 1864.

Institute of Geology of Mine Deposits,
Petrography, Minerals and Geochemistry,
Academy of Sciences, U. S. S. R.
Moscow

Received, 12 May 1959

REVIEWS AND DISCUSSIONS

THE DISCUSSION OF SYSTEMS WITH FULLY MOBILE COMPONENTS AND THEIR THERMODYNAMIC POTENTIALS[1]

by

D. S. Korzhinskiy

In connection with the conclusions recently published by the Committee on Thermodynamics of the Division of Chemical Sciences of the Academy of Sciences of the U. S. S. R. [1], it is in order to set forth here the history of this discussion.

An analysis of mineral parageneses in nature as early as 1936 led the present writer to formulate his conception of systems with fully mobile components [2] — that is, thermodynamic systems in which the independent parameters of certain components, designated as "fully mobile", are not their masses (as would be true of "inert" components), but their chemical potentials. In other words, the external conditions of the system may be given not only in terms of temperature and pressure, but also by the chemical potentials of the fully mobile components.

The conceptions which I developed regarding systems with fully mobile components and the application of the Gibbs phase rule to them [3, 4, 6] were met by distrust on the part of geologists from the very beginning. The geologists were convinced that "the phase rule applies only to closed systems" (this erroneous statement may be found in some textbooks), and on this basis my method of analysis of mineral parageneses was considered by many to be of doubtful validity. I was therefore compelled to request the Division of Chemical Sciences of the Academy of Sciences of the U. S. S. R. to allow me to present a report to specialists on thermodynamics. Accordingly, a meeting was held on March 8, 1949, which heard my report on "Systems with Fully Mobile Components and the Phase Rule", at the Institute of General and Inorganic Chemistry of the Academy of Sciences of the U. S. S. R., in the presence of a number of specialists in physical chemistry and thermodynamics, as well as geologists. The remarks by Professor V. Ya. Anosov, V. A. Kireyev, K. V. Astakhov, V. S. Kiselev and Ya. I. Ol'shanskiy, all of whom attended the meeting, confirmed the truth of my conclusions. This meeting was of great importance to the geologists, since it dispelled the suspicion of my method of analysis of mineral parageneses.

In 1949, in a report to the Second All-Union Conference on Physicochemical Analysis, I presented the thermodynamic potentials of some systems with fully mobile components [5]. Of the four new potentials, I shall cite here as an example only the single potential Z_O, obtained from the usual isothermal-isobaric Gibbs potential:

$$Z = U - TS + pV = \sum_{a}^{N} \mu_i m_i$$

by subtracting the product $\mu_j m_j$, which is related to the fully mobile components:

$$Z_0 = Z - \sum_{j}^{k} \mu_j m_j = \sum_{a}^{l} \mu_i m_i;$$

(Z - is the isothermal-isobaric Gibbs potential; U - is the internal energy of the system; T - is the absolute temperature; S - is the entropy; p - is the pressure; V - is the volume of the system; μ_i, m_i - are the chemical potential and the mass of the component i, respectively; $\alpha, \ldots i$ are the inert components; i. . . , k are the fully mobile components of the system).

The substantive differential of the system with fully mobile components is expressed as follows:

$$dZ_0 = -SdT + Vdp + \sum_{a}^{l} \mu_i dm_i - \sum_{j}^{k} m_j d\mu_j.$$

---

[1]Diskussiya o sistemakh s vpolne podvizhnymi komponentami i ikh termodinamicheskikh potentsialakh.

Similarly, from the thermodynamic potentials U, H and F (the internal energy, the heat capacity and the free energy) by subtracting $\Sigma m_j \mu_j$ we obtain the corresponding potentials of systems with the fully mobile components U_O, H_O and F_O.

Later I presented a more detailed mathematical analysis of these functions [7, 8].

The functions proposed by me were sharply criticized in papers by V. A. Nikolayev [9, 10, 11], who came to the conclusion that these functions were completely absurd. V. A. Nikolayev even presents the semblance of a mathematical proof of this absurdity, which he arrives at by very strange means. In particular, at the beginning of his line of reasoning V. A. Nikolayev proceeds from my definition of

$$Z_O = Z - \Sigma_j^k \mu_j \cdot m_j,$$

but at the end he arbitrarily equates $Z_O = U - TS + pV$ (that is, $Z_O = Z$), which of course leads to a result that does not make sense [9, pp. 315 - 316]. Moreover he not only fails to explain this replacement of one function by another, but does not even mention it, so that the majority of his geologist readers undoubtedly failed to notice the replacement. This same outwardly effective but actually defective conclusion is repeated in another paper by V. A. Nikolayev [10, p. 62].

Unfortunately the editors of the journal "Zapiski Vsesoyuznogo Mineralogicheskogo Obshchestva" ("Notes of the All-Union Mineralogical Society"), which printed the very sharply critical article by V. A. Nikolayev, declined to publish my answering article, in which I called the readers' attention to this and other errors in V. A. Nikolayev's arguments. This refusal is a departure from the tradiation of Soviet journals and is doubtless the result of an unintentional oversight on the part of the editorial board. My brief note with a reference to the conclusion reached by the Committee on Thermodynamics (see below) was also returned to me unpublished by the editors of "Zapidki Vsesoyuznogo Mineralogicheskogo Obshchestva".

An article by A. V. Storonkin [12] appearing immediately thereafter acknowledged that the potential functions I had put forth are "to some degree new characteristic functions". "The derivation of these functions, from the standpoint of the theory of characteristic functions, is fully justified" [12, pp. 77 - 78]. Hence it would seem that A. V. Storonkin understood the error of V. A. Nikolayev's conclusion that, even from the purely mathematical standpoint, these functions were completely absurd. Nevertheless he writes of the "proper criticism of D. S. Korzhinskiy's conclusions" made by V. A. Nikolayev [12, p. 78]. A. V. Storonkin denies that these functions are thermodynamic potentials, since the "thermodynamic properties of the systems, regardless of the degree of their material isolation, are described by the same potentials" [specifically, U, F, H and Z; 12, p. 77].

In my book I was forced to limit myself to a brief consideration of V. A. Nikolayev's objections [8, pp. 35 - 36]. In the meantime I requested the Division of Geologic-Geographic Sciences of the Academy of Sciences of the U. S. S. R. to draw the attention of specialists in chemical thermodynamics to our discussion. At the beginning of 1956 the Division requested the Bommittee on Thermodynamics of the Division of Chemical Sciences of the Academy of Sciences of the U. S. S. R. to consider our controversy. The Committee examined all the published papers by V. A. Nikolayev, D. S. Korzhinskiy and A. V. Storonkin that have a bearing on the discussion, and also additional manuscripts setting forth the basic positions of these authors and written specially for the Committee. On April 17, 1957 a meeting of the Committee heard my report on "Systems with Fully Mobile Components and their Thermodynamic Potentials" and a critical report by V. A. Nikolayev. A. V. Storonkin was absent, but the remarks sent in by him were read. Thereafter the Committee studied the materials and, after additional discussion within the Committee, came to the decision that was published in the journal "Geokhimiya" ("Geochemistry") [1].

Of the four potentials proposed by me, this conclusion by the Committee as a representative example considers the most important thermodynamic potential Z_O. The article proves that "Z_O is the thermodynamic potential of the system as established under the given conditions (that is, where T, p. $m_{\alpha} \ldots$, m_i, $\mu_j \ldots$ and μ_k are constant).

Thus the concept of thermodynamic systems with fully mobile components and their thermodynamic potentials has finally been granted the "rights of citizenship". These conceptions, as I have stated, are derived directly from Gibbs' thermodynamics. I can agree in part with those of my reviewers who assert that "this contains nothing new in comparison with Gibb's thermodynamics". The more than twenty years of discussion, however, indicate that there is in this something new in matters of principle. Physical chemistry chemical and thermodynamics were developed on the basis of laboratory chemistry and laboratory technology. New fields of application, particularly to the analysis of mineral forming processes occurring in nature, have inevitably led to an unusual posing of the problem and required new physicochemical concepts, which are unfamiliar to chemists and sometimes contradict the traditional formulations in the textbooks. This explains the heated and tense discussion of the physicochemical principles underlying the analysis of mineral formations.

REFERENCES

1. Gerasimov, Ya. I., O termodinamicheskikh potentsialakh sistemy s vpolne podvizhnymi komponentami, predlagayemykh D. S. Korzhinskim. [THERMODYNAMIC POTENTIALS OF A SYSTEM WITH FULLY MOBILE COMPONENTS, PROPOSED BY D. S. KORZHINSKIY]: Geokhimiya, no. 5, 1959.

2. Korzhinskiy, D. S., Podvizhnost' i inertnost' komponentov pri metasomatoze. [THE MOBILITY AND INERTIA OF COMPONENTS IN METASOMATISM]: Izv. Akad. Nauk SSSR, ser. geol., no. 1, 1936.

3. Korzhinskiy, D. S., Pravilo faz i sistemy s vpolne podvizhnymi komponentami. [THE PHASE RULE AND SYSTEMS WITH FULLY MOBILE COMPONENTS]: Dokl. Akad. Nauk SSSR, t. 64, no. 3, 1949.

4. Korzhinskiy, D. S., Otkrytyye sistemy s vpolne podvizhnymi komponentami i pravilo faz. [OPEN SYSTEMS WITH FULLY MOBILE COMPONENTS AND THE PHASE RULE]: Izv. Akad. Nauk SSSR, ser. geol., no. 2, 1949.

5. Korzhinskiy, D. S., Termodinamicheskiye potentsialy otkrytykh sistem i primer ikh primeneniya v geokhimii. [THE THERMODYNAMIC POTANTIALS OF OPEN SYSTEMS AND AN EXAMPLE OF THEIR APPLICATION IN GEOCHEMISTRY]: Izv. sektora fiz. -khim. analiza Akad. Nauk SSSR, t. 19, 1949.

6. Korzhinskiy, D. S., Faktory ravnovesiya pri metasomatoze. [EQUILIBRIUM FACTORS IN METASOMATISM]: Izv. Akad. Nauk SSSR, ser. geol., no. 3, 1950.

7. Korzhinskiy, D. S., Vyvod termodinamicheskikh potentsialov sistem s podvizhnymi komponentami. [THE DERIVATION OF THE THERMODYNAMIC POTENTIALS OF SYSTEMS WITH MOBILE COMPONENTS]: Dokl. Akad. Nauk SSSR, t. 106, no. 2, 1956.

8. Korzhinskiy, D. S., Fiziko-khimicheskiye osnovy analiza parageneza mineralov. [THE PHYSICOCHEMICAL PRINCIPLES OF ANALYZING MINERAL PARAGENESIS]: Izd-vo Akad. Nauk SSSR, 1957.

9. Nikolayev, V. A., Ob odnom iz osnovnykh uravneniy termodinamiki i yego primenenii k otkrytm sistemam. [ONE OF THE PRINCIPAL EQUATIONS OF THERMODYNAMICS AND ITS APPLICATIONS TO OPEN SYSTEMS]: Zap. Vses, mineralog. o-va, ch. 83, no. 4, 1954.

10. Nikolayev, V. A., K voprosam teorii ravnovesnykh protsessov i ikh znachenii v genezise magmaticheskikh i metamorficheskikh porod. [ON THE THEORY OF EQUILIBRIUM REACTIONS AND THEIR IMPORTANCE IN THE GENESIS OF IGNEOUS AND METAMORPHIC ROCKS]: Tr. Labor. geol. dokembriya, vyp. 5, 1955.

11. Nikolayev, V. A., Ob uravneniyakh, vyrahayushchikh izmeneniya potentsiala zakrytykh i otkrytykh sistem. [ON THE EQUATIONS EXPRESSING THE CHANGES IN THE POTENTIAL OF CLOSED AND OPEN SYSTEMS]: Dokl. Akad. Nauk SSSR, t. 106, no. 1, 1956.

12. Storonkin, A. V., Nekotoryye voprosy termodinamiki sistem, podchinennykh usloviyam material'noy izolyatsii. [SOME PROBLEMS OF THE THERMODYNAMICS OF SYSTEMS UNDER CONDITIONS OF MATERIAL ISOLATION]: Vestn. Leningr. un-ta, no. 16, 1956.

CONCERNING M. F. VEKLICH'S BOOK "QUATERNARY DEPOSITS ON THE RIGHT BANK OF THE MIDDLE REACHES OF THE DNEPR RIVER"[2]

by

N. A. Kunitsa

In 1959 the Academy of Sciences Press of the Ukrainian S. S. R. published a monograph by M. F. Veklich on the subject of the Quaternary deposits in a region embracing the Kiev and Zhitomir Poles'ye region, the Dnepr River area and the eastern part of the Volyno-Podolian highland. Most of this territory is located within the Ukrainian crystalline shield, and a smaller part in the transitional zone between the shield and the Dnepr-Donets Basin.

The book has 198 pages, consisting of three parts: 1) the composition of the Quaternary mantle, 2) the lithology of the Quaternary deposits and 3) the conditions of formation of the Quaternary deposits. The work is illustrated by fourteen tables showing the petrographic, chemical, and mammalian faunal composition of the Quaternary deposits, by 71 figures, by particularly numerous geologic sections, by lithologic, tectonic, paleogeographic and paleopedologic sketch maps and by diagrams showing the distribution of the molluscs, as well as a map of the Quaternary deposits.

---

[2]O knige M. F. Veklicha "Chetvertinni vidkladi pravoberezhzhya seredn'ogo Dnipra."

In spite of the prolonged study of the Quaternary mantle in this region by numerous investigators, and the accumulation of a large amount of factual material, a summarizing work on the Quaternary geology of the right bank area of the Middle Dnepr River has not existed up to the present time. This, however, is not the only value of the monograph reviewed here. The importance of this book consists in the following: 1) the author has studied the Quaternary mantle by a combination of methods: lithologic, mineralogical, paleontological, geomorphological, paleopedological, etc.; certain of these methods, such as the geomorphological and paleopedological, have been considerable improved; 2) the author's theoretical conclusions are based on a large quantity of analytical data, including those obtained by new methods of investigation such as thermal and chromatographic studies of clay minerals; 3) this has, in turn, enabled the author to analyze data of old and new investigations more thoroughly and reliably; 4) his thorough and many-sided complex study of the Quaternary mantle has enabled the author to express some significantly original views on particular problems connected with the Quaternary rocks of the area and the mineral raw materials associated with them. The most important and basic consideration, however, is that this monograph presents the results of eight years of field work and laboratory investigations made by the author at the level of modern scientific practice and theory in the field of Quaternary geology.

On the basis of his investigations, the author has made a number of important conclusions regarding especially the loessial rocks — this widespread component of the Quaternary mantle — their distribution, mode of occurrence, genesis, stratification and stratigraphy. For example, the paper shows convincingly that the loesses are of different origins — deluvial, aqueous-glacial, alluvial, alluvial-deluvial and eluvial. The most widespread are the deluvial loesses, which make up some 90% of the area covered by loessial deposits. This overthrows the conception, commonly held in the literature, that the Middle Dnepr is a region of typical development of aeolian loess. Objective analysis of the rich, including recent, factual material has provided the author with the basis for making a stratigraphic subdivision of the Quaternary system along the right bank of the Middle Dnepr River.

The structure of the Quaternary mantle (first part of the book) is examined by the author successively according to the areas in which the lithologic, genetic and chronological varieties of mantle deposits are distributed: 1) glacial and periglacial and 2) extraglacial.

Within the first region he distinguishes morainal-outwash and outwash areas (Poles'ye), and glacial and glacial loessial areas. For each area there are summarizing and typical concrete sections through the Quaternary deposits of various geomorphological elements — interstream areas, slopes and river valleys.

It should be noted that by means of geomorphological analysis the author has been able to make a clear distinction between two categories of interstream areas — primary and secondary — with different conditions of accumulation of the Quaternary deposits — and thereby to eliminate the stratigraphic discrepancies of certain previous investigators. It is established that the Quaternary strata of primary interstream areas have a different structure from that of secondary interstream areas and slopes. The latter have a more-or-less thick mantle of deluvial loess, divided by fossil soils. Fossil soils are lacking in primary interstream areas.

The author has made a detailed study of the geologic structure of the glacial and fluioglacial relief forms: shoved moraines, dislocations cuased by glaciers, glacial erratics and especially fluvioglacial valleys, eskers and kames. The author believes that the dislocated stratum of the Kanev area is an accumulation of erratics lying upon the almost undislocated rocks of the Paleogene and Mesozoic. He sees the cause of these dislocations in glacial tectonics.

The author has generalized from the data of his predecessors and from his own investigations of fluvioglacial valleys, and has made a detailed study of their distribution, morphology and geologic structure. He has also determined that the glacial relief forms which were earlier described as terminal moraines are actually eskers and kames.

The second part of the book considers the lithology of the moraines, the fluvioglacial, deluvial, alluvial-deluvial and alluvial deposits, fossil soils and other genetic types of deposits, according to the following pattern: 1) distribution and mode of occurrence, 2) structure and texture, 3) mineralogical and chemical composition, 4) fauna.

Three areas of distribution are distinguished, on the basis of the petrographic composition of the fragments in the moraine: a western (Zhitomir) area with a predominance of fragments of local rocks, an eastern (Dnepr) area in which the leading role is played by fragments of rocks carried in from the north, and a central area in which neither local rocks nor rocks carried in from the north are predominant. On the basis of lithology, an upper and a lower stratum have been distinguished in the moraine. The mineral composition of the moraine is not preserved; nevertheless there is a rich fauna of terrestrial and fresh-water molluscs, which are apparently allochthonous.

It has been established that the Middle Dnepr area contains a fluvioglacial loess, which is

essentially a carbonate weathering crust of fluvioglacial clay loams and sandy loams. In the interstream areas of the glaciated region this loess is the parent rock of the modern soil.

Much new material has been introduced into the study of the most widespread genetic types of Quaternary deposits — deluvial and alluvial-deluvial. The author has determined the basic stratificational indication of the deluvium-fossil soils. On the basis of its inherited minerals, the deluvial loess has been found to contain two layers: an upper layer developed everywhere throughout the glaciated region and in the extraglacial area within the river valleys which served as channels for the fluvioglacial outwash waters of the Dnepr glaciation, and a lower layer which in the glacial and periglacial areas is covered by a complex of glacial deposits, but in the extraglacial area is exposed at the surface.

In each individual section it has also been established that there is an identity between the quantitative and qualitative composition of the inherited minerals in the upper layer of the deluvial loess, the moraines and the fluvioglacial deposits, indicating that in each case their source was the same.

The ecological composition of the molluscs in the deluvial loess (a predominance of psychrophylic and mesophylic elements) shows that these deposits could not have been formed under dry or desert conditions.

The fossil soils, their distribution, occurrence and types, have been studied with fairly great detail. The author's chief conclusions may be formulated as follows: 1) in the supermorainal layer of the loess area, the fossil soils are developed only on slopes, secondary interstream areas and terraces, and do not occur in the primary interstream areas, thus contradicting the view commonly held in the literature that such soils are universally distributed and preserved; 2) the chief types of fossil soils are gray forest soils, brown soils and red-brown chernozems; 3) all these soils are stratigraphic datum planes; 4) all the other types of soils — swampy, silty-gley and podzolic — are of very limited distribution; 5) the fossil soils, if one considers the paleontological, lithological and other data, may be used for stratigraphic purposes and especially for reconstructing the physical geographic conditions during the time of their formation.

A striking feature of the description of the alluvial deposits is the hypsometric relationship of the alluvium of the rivers in the glacial, periglacial and extraglacial areas, and also the determination of the geologic ages of the three basic generations of alluvium. The author believes that the deposits of the third terrace — that of the Dnepr, Ingul'ts, Ingul and Southern Bug Rivers — in the extraglacial area are part of an alluvial suite formed during the time from the beginning of the Quaternary period to the end of the Dnepr glaciation inclusive. The alluvium of the middle (second) terrace of the Dnepr and Southern Bug River basins, like that of the third and fourth terraces of the Dnestr River, is younger than the Dnepr moraine.

The identical composition of the inherited accessory minerals, as established by the author in each concrete section through the terrace loess and the underlying clearly alluvial deposits, indicates that they have a common source. Hence it follows that the terrace loess is also of alluvial origin.

The third part of the book is a synthesis of the information set forth in the first two parts. Here the author draws his conclusions regarding the conditions of formation of the Quaternary deposits. Three epochs are distinguished: an Early Quaternary (Q_1), a Middle Quaternary (Q_2) with Dnepr (Q_2^1) and Poles'ye (Q_2^2) ages and a Late Quaternary (Q_3) epochs. The general features of the paleogeography are characterized: the tectonics and relief, the physical geographic conditions and the lithogenesis of each epoch, as well as a complex of specific paleontological and lithologic criteria for each subdivision of the Quaternary system. In conclusion, the author furnishes a stratigraphic subdivision of the Quaternary deposits of the interstream areas, slopes and valleys of the Poles'ye and the loessial areas of the glacial, periglacial and extraglacial regions, and some generalizations from the data on the mammalian and molluscan fauna and the tectonic movements.

The reader of M. V. Veklich's book will be struck by the breadth and scope of the new problems which the author has posed and, in general, properly and convincingly solved, in his study of this region of varied Quaternary deposits.

The reviewer finds no disagreement with the basic statements and conclusions of the author. Nevertheless the book contains some defects. Above all, there is no comparison made between the author's stratigraphic schemes and the more widely known schemes of other investigators, which creates obstacles to the practical utilization of this book, especially by field workers. It is also unfortunate that the monograph has devoted little attention to a critical analysis of other views, particularly those on such interesting problems as the subdivision of the Quaternary system into four sections, as well as the hypothesis of the aeolian origin of the Ukrainian loesses, although the data cited in the book clearly contradict these opinions.

The author has also paid little attention to the study of the so-called "Carpathian gravels", which are widespread in the Middle Dnestr River

area and in the basin of the middle part of the Southern Bug River. If, as the author supposes (p. 155), these gravels belong in the Quaternary Baltic suite, how is one to explain the presence of these gravels on the high interstream areas north of the area of distribution of the Baltic suite?

It is also difficult to understand where, in the stratigraphic scheme worked out by the author, to place the alluvial formations of the first and second terraces of the Dnestr River. Some places in the Dnestr valley preserve the remnants of the very oldest, seventh (180 - 220 m) terrace, which is apparently of pre-Quaternary age. There is no mention of this in the book.

In this reviewer's opinion, the author has also insufficiently explained the conditions of formation of the loess in the loessial remnants of the Poles'ye, if it is recalled that its formation is directly associated with fluvioglacial accumulations. There is no explanation of the role played by tectonics in the change and the distribution of the fluvioglacial facies and their association with the process of loess formation.

The above reservations, however, are not of decisive importance in evaluating M. F. Veklich's book. It is without exception both interesting and useful, and may be utilized in practical and scientific research work by specialists working in Quaternary geology, geomorphology, physical geography, soil science, geologic mapping and in the location of placer and other economic mineral deposits.

BIBLIOGRAPHY

LITERATURE ON GEOLOGY AND RELATED DISCIPLINES RECEIVED AT THE LIBRARY OF THE GEOLOGIC-GEOGRAPHIC SCIENCES BRANCH OF THE U.S.S.R. ACADEMY OF SCIENCES IN JANUARY AND FEBRUARY, 1960

A. Articles in Periodicals

GEOLOGY

1. Abdullayev, R.N., Kazakhskiy kompleks tseolitsoderzhashchikh vulkanicheskikh porod (Malyy Kavkaz). [THE KAZAKH COMPLEX OF ZEOLITE-CONTAINING VOLCANIC ROCKS (LESSER CAUCASUS]: Izv. Akad. Nauk AzerbSSR, ser. geol. geogr. nauk, no. 6, 1959.

2. Azizbekov, Sh.A., M.B. Zeynalov, and T.G. Gadzhiyev, Analiz fatsiy i moshchnostey srednemiotsenovykh otlozheniy Nakhichevanskoy vpadiny. [ANALYSIS OF THE FACIES AND THICKNESSES OF THE MIDDLE MIOCENE DEPOSITS OF THE NAKHICHEVAN BASIN]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 11, 1959.

3. Azizbekov, Sh.A., and A.E. Bagirov, Ritmostratigraficheskoye raschleneniye yurskikh i melovykh otlozheniy Nakhichevanskoy skladchatoy oblasti. [A CYCLICAL STRATIGRAPHIC SUBDIVISION OF THE JURASSIC AND CRETACEOUS DEPOSITS OF THE NAKHICHEVAN FOLDED REGION]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr., nauk, no. 6, 1959.

4. Amanov, S., O kontakte akchagyl'skogo i apsheronskogo yarusov Kumdaga (Turkmeniya). [ON THE CONTACT BETWEEN THE AKCHAGYL AND APSHERON STAGES OF KUMDAG (TURKMENIA)]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 11, 1959.

5. Babak, V.I., Ocherk neotektoniki Kryma. [OUTLINE OF THE NEOTECTONICS OF THE CRIMEA]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

6. Bagdasarova, A.M., i dr., Seysmichnost' vostochnoy chasti yuzhnykh otrogov Glavnogo Kavkazskogo khrebta i nekotoryye metodicheskiye voprosy izucheniya seysmichnosti otdel'nykh rayonov. [SEISMIC ACTIVITY IN THE EASTERN PART OF THE SOUTHERN SPURS OF THE MAIN CAUCASUS RANGE AND SOME METHODOLOGICAL PROBLEMS OF STUDYING THE SEISMIC ACTIVITY OF PARTICULAR AREAS]: Izv. Akad. Nauk AzerbSSR, ser., geol.-geogr. nauk, no. 6, 1959.

7. Barkovskaya, M.G., Zakonomernosti raspredeleniya oblomochnogo materiala v polose plyzaha Chernogo morya. [THE LAWS GOVERNING THE DISTRIBUTION OF CLASTIC MATERIAL IN THE BEACH ZONE OF THE BLACK SEA]: Vestn. LGU, no. 24, ser. geol. i geogr., vyp. 4, 1959.

8. Beznosov, N.V., V.P. Kazkova, Yu.G. Leonov and D.I. Panov, Stratigrafiya nizhney i sredney yury Tsentral'nogo Kavkaza. [THE STRATIGRAPHY OF THE LOWER AND MIDDLE JURASSIC IN THE CENTRAL CAUCASUS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

9. Bezrukov, P.L. and E.A. Romankevich, K stratigrafii i litologii donnykh otlozheniy severo-zapadnoy chasti Tikhogo okeana. [THE STRATIGRAPHY AND LITHOLOGY OF THE BOTTOM DEPOSITS IN THE NORTHWESTERN PART OF THE PACIFIC OCEAN]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

10. Belostotskiy, I.I. i dr., Tektonicheskoye rayonirovaniye Altaye-Sayanskoy gornoy oblasti. [THE TECTONIC REGIONALIZATION OF THE ALTAY-SAYAN MOUNTAIN REGION]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

11. Belyayevskiy, N.A., Geologicheskaya sluzhba Tangan'iki. [THE GEOLOGICAL

SERVICE OF TANGANYIKA]: Byul. nauch.-tekhn. inform M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

2. Belyayevskiy, N.A., A.V. Grigor'yev and Yu.A. Ivanov, Napravleniye i zadachi geologicheskogo kartirovaniya territorii SSSR. [THE TRENDS AND TASKS OF GEOLOGIC MAPPING WITHIN THE USSR]: Sov. geol., no. 12, 1959.

3. Blank, M.I., and N.Ye. Kanskiy, O gipsonosnykh otlozheniyakh verkhnego kimeridzha Dneprovsko-Donetskoy vpadiny. [THE UPPER KIMMERIDGIAN GYPSIFEROUS DEPOSITS OF THE DNEPR-DONETS BASIN]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

4. Bondareva, T.P., V.I. Samodurov and M.Ya. Serova, Znacheniye miliolid dlya stratigrafii paleogena Aralo-Turgayskoy nizmennosti. [THE IMPORTANCE OF MILIOLIDAE FOR THE PALEOGENE STRATIGRAPHY OF THE ARAL-TURGAY LOWLAND]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

5. Botvinkina, L.N., Geneticheskiye tipy kosoy sloistosti. [GENETIC TYPES OF CROSS BEDDING]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

6. Bronguleyev, V.V., K probleme proiskhozhdeniya i klassifikatsii skladok. [THE PROBLEM OF THE ORIGIN AND CLASSIFICATION OF FOLDS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

7. Buvalkin, A.K., O prichinakh rasshchepleniya moshchnykh ugol'nykh plastov Maykyubenskogo basseyna. [THE REASONS FOR THE BRANCHING OF THE THICK COAL SEAMS OF THE MAYKYUBNYY BASIN]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 4(37), 1959.

8. Bulavin, B.P., Perspektivy geologicheskikh issledovaniy na Azovskom poberezh'ye. [THE PROSPECTS OF GEOLOGICAL INVESTIGATIONS ON THE SHORES OF THE SEA OF AZOV]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

19. Bushinskiy, G.I., O diageneze kembriyskoy siney gliny okrestnostey Leningrada. [THE DIAGENESIS OF THE CAMBRIAN BLUE CLAYS IN THE VICINITY OF LENINGRAD]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

20. Byurg, G., Medenosnyye peschaniki basseyna r. Ebro v Severnoy Ispanii. [THE CUPRIFEROUS SANDSTONES IN THE EBRO RIVER BASIN IN NORTHERN SPAIN]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 7(24), 1959.

21. Vaznyachuk, L.M., Umovy zalyagannya rys-vyurmskikh adkladannyau u Grodzenskay v oblastsi i sumezhnykh rayënakh litvy i Pol'shchy. [THE CONFORMABLE OCCURRENCE OF THE RISS-WUERM DEPOSITS IN THE GRODNO AREA AND THE ADJACENT AREAS OF LITHUANIA AND POLAND (IN BELORUSSIAN]: Vestsi Akad. Nauk BSSR, ser. fiz.-tekhn. nauk, no. 4, 1959.

22. Velikovskaya, Ye.M., and A.A. Steklov, O verkhnesarmatskikh otlozheniyakh basseynov rek Bol'shoy Laby i Beloy. [THE UPPER SARMATIAN DEPOSITS IN THE BASINS OF THE BOL'SHAYA LABA AND BELAYA RIVERS]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

23. Viktorov, S.V., Litologo-geokhimicheskiye fatsii kory vyvetrivaniya v pustynyakh i rastitel'nyy pokrov. [THE VEGETATIVE COVER AND THE LITHOLOGIC-GEOCHEMICAL FACIES OF THE WEATHERING CRUST IN DESERTS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

24. Vlasova, M.I., Novyye dannyye po geologii yuzhnoy chasti Yuzhnogo Kara-Mazara. [NEW DATA ON THE GEOLOGY OF THE SOUTHERN PART OF THE SOUTHERN KARA-MAZAR]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

25. Volkov, I.A., Khvalynskiye otlozheniya Zapadnykh Karakumov. [THE KHVALYNIAN DEPOSITS OF THE WESTERN KARAKUMY]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

26. Vyshivkin, D.D., Geokhimicheskiye landshafty p-ova Mangyshlak. [GEOCHEMICAL TOPOGRAPHIES IN THE MANGYSHLAK PENINSULA]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

27. Galitskiy, V.V., K teorii formirovaniya dolin. [ON THE THEORY OF VALLEY FORMATION]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

28. Glebovskiy, Yu.S., Podlednyy khrebet Braun-Gauss. [THE BRAUN-HAUSS SUBGLACIAL RIDGE]: Inform. byul. sov. Antarkt. eksp., no. 11, 1959.

29. Gorin, V.A., Sovremennyye iskopayemyye i kirovyye pokrovy Apsheronskogo poluostrova. [THE MODERN FOSSILS AND THE SOLIDIFIED PETROLEUM CRUSTS OF THE APSHERON PENINSULA]: Dokl. Akad. Nauk AzerbSSR, t. 15, no. 12, 1959.

30. Gramm, M.N., Skhema deleniya tretichnykh

kontinental'nykh otlozheniy Ferganskoy vpadiny. [A SCHEME FOR THE SUBDIVISION OF THE TERTIARY CONTINENTAL DEPOSITS OF THE FERGANA VALLEY]: Uzb. geol. zh., no. 6, 1959.

31. Gromov, Yu. Ya., Tektonika i istoriya formirovaniya Ussuri-Khankayskogo sredinnogo massiva. [THE TECTONICS AND THE HISTORY OF FORMATION OF THE USSURI-KHANKAY INTERIOR MASSIF]: Sov. geol., no. 12, 1959.

32. Gusev, A.M., K opredeleniyu absolyutnykh vysot ledyanogo kupola Antarktidy. [DETERMINING THE ABSOLUTE ELEVATIONS OF THE ICE DOMES OF ANTARCTICA]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

33. Dorman, M.I., and A.A. Nikolayevskiy, Novyye dannyye o geologicheskom stroyenii Vilyuyskoy sineklizy. [NEW DATA ON THE GEOLOGIC STRUCTURE OF THE VILYUY SYNECLISE]: Geol. nefti i gaza, no. 1.

34. Yerokhov, V.F., Novyye dannyye o vozraste neogenovykh obrazovaniy severo-vostochnoy chasti o. Iturup (Kuril'skiye Ostrova). [NEW DATA ON THE AGE OF THE NEOGENE FORMATIONS IN THE NORTHEASTERN PART OF ITURUP ISLAND (IN THE KURILE ISLANDS)]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

35. Yefremov, Yu.K., Landshaftnaya sfera zemli. [THE EARTH'S TOPOGRAPHIC SPHERE]: Izv. Vses. geogr. o-va, t. 91, vyp. 6, 1959.

36. Zhizhchenko, B.P., Oblasti snosa terrigennogo materiala i dvizheniya zemnoy kory. [AREAS OF ABLATION OF TERRIGENOUS MATERIAL AND THE MOVEMENTS OF THE EARTH'S CRUST]: Sov. geol., no. 12, 1959.

37. Zhuravlev, V.S., and Yu.Ya. Kuz'min, O predpolagayemom Azgirskom razlome v yuzhnoy chasti mezhdurech'ya Urala i Volgi. [ON THE SUPPOSED AZGIR FAULT IN THE SOUTHERN PART OF THE INTERSTREAM REGION BETWEEN THE URAL AND THE VOLGA RIVERS]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

38. Zindel', L.A., and Kh.Kh. Avazkhodzhayev, K litologii yurskikh otlozheniy basseyna R. Yassy (Ferganskiy Khrebet). [THE LITHOLOGY OF THE JURASSIC DEPOSITS IN THE YASSA RIVER BASIN (FERGANA RANGE)]: Uzb. geol. zh., no. 6, 1959.

39. Zor'kin, Ya.M., A.N. Simonenko, Yu.A. Fedotov and I.V. Kushnirov, O tektonicheskom stroyenii fundamenta Bukharo-Khibinskoy gazoneftenosnoy oblasti. [THE TECTONIC STRUCTURE OF THE BASEMENT OF THE BUKHARA-KHIVA GAS AND OIL REGION]: Doklady, Akad. Nauk UzSSR, no. 12, 1959.

40. Kazanin, Yu.I., N.A. Pigulevskiy, A.E. Shlygin and P.K. Zhukov, Novyye dannyye o skladchatykh strukturakh rudovmeshchayushchikh nizhnepaleozoyskikh tolshch Dzhungarskogo Alatau. [NEW DATA ON THE FOLDED STRUCTURES OF THE ORE-BEARING LOWER PALEOZOIC STRATA OF THE DZHUNGARSKIY ALATAU]: Iav. Akad. Nauk KazSSR, ser. geol., vyp. 4(37), 1959.

41. Dmitriy Nikolayevich Kazanli. Nekrolog. [DMITRIY NIKOLAYEVICH KAZANLI: OBITUARY]: Vestn. Akad. Nauk KazSSR, no. 11, 1959.

42. Kamaletdinov, M.A., and R.A. Kamaletdinov, Novyye dannyye o devone basseyna r. B. Ik na Yuzhnom Urale. [NEW DATA ON THE DEVONIAN BASIN OF THE BOL'SHOY IK RIVER IN THE SOUTHERN URALS]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

43. Karpov, P.A., Devonskiye otlozheniya Stalingradskoy oblasti. [THE DEVONIAN DEPOSITS OF THE STALINGRAD AREA]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

44. Kozhevnikov, A.V., Proiskhozhdeniye "pokrovnykh" suglinkov v doline kubani i na prilegayushchikh vodorazdelakh. [THE ORIGIN OF THE "CRUSTOSE" CLAY LOAMS IN THE KUBAN RIVER VALLEY AND THE ADJACENT INTERSTREAM AREAS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

45. Kondorskaya, I.V., and V.I. Tikhonov, K. voprosu o seysmichnosti i tektonike Kamchatki i severnoy chasti Kuril'skoy gryady. [THE PROBLEM OF THE SEISMIC ACTIVITY AND TECTONICS OF KAMCHATKA AND THE NORTHERN PART OF THE KURILE RANGE]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

46. Koptev-Dvornikov, V.S., Voprosy terminologii, imeyushchiye otnosheniye k izucheniyu geologii izverzhennykh porod. [PROBLEMS OF TERMINOLOGY WITH REFERENCE TO THE GEOLOGY OF IGNEOUS ROCKS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

47. Koronovskiy, N.V. Proyavleniye vulkanicheskoy deyatel'nosti v verkhnechetvertichnoye vremya v Zapadnom Priel'bruse. [THE OCCURRENCE OF VOLCANIC ACTIVITY IN THE LATE QUATERNARY

IN THE WESTERN ELBRUS REGION]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

. Kossovskaya, A.G., O spetsifike epigeneticheskikh izmeneniy terrigennykh porod v usloviyakh platformennoy i geosinklinal'noy oblastey. [ON THE SPECIFIC EPIGENETIC CHANGES IN TERRIGENOUS ROCKS UNDER THE CONDITIONS OF PLATFORM AND GEOSYNCLINAL REGIONS]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

. Kronidov, I.I., and A.A. Dukhovskiy, Nekotoryye voprosy metodiki interpretatsii aeromagnitnykh dannykh na territorii Kazakhstana. [SOME METHODOLOGICAL PROBLEMS OF INTERPRETING AEROMAGNETIC DATA IN THE TERRITORY OF KAZAKHSTAN]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 4(37), 1959.

). Krylkov, Yu.V., Periglyatsial'nyye otlozheniya Yuzhnogo Tadzhikistana, ikh sopostavleniye s otlozheniyami Kamskogo basseyna i inzhenerno-geologicheskoye znacheniye ikh vydeleniya. [THE PERIGLACIAL DEPOSITS OF SOUTHERN TADZHIKISTAN, THEIR CORRELATION WITH THE DEPOSITS OF THE KAMA RIVER BASIN, AND THE ENGINEERING GEOLOGIC SIGNIFICANCE OF THEIR IDENTIFICATION]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

1. Kushlin, B.K., Novyye dannyye o vozraste istykskoy svity i svity chechektinskikh konglomeratov. [NEW DATA ON THE AGE OF THE ISTYK FORMATION AND THE CHECHEKTA FORMATION OF CONGLOMERATES]: Sov. geol., no. 12, 1959.

2. Larin, V.I., O metodike izucheniya glubiny razryvnykh smeshcheniy (na primere skladok Pribalkhanskogo rayona). [ON THE METHODS OF STUDYING THE DEPTHS OF RUPTURE DISPLACEMENTS (FROM THE EXAMPLE OF THE FOLDS IN THE BALKHAN REGION)]: Novosti nefti tekhniki, geologiya, no. 12, 1959.

3. Lauyenkrapch, Ye., Kharakteristika nekotorykh pochv Latviyskoy SSR, obrazovavshikhsya na devonskikh otlozheniyakh. [A CHARACTERIZATION OF CERTAIN SOILS OF THE LATVIAN SSR, FORMED ON DEVONIAN DEPOSITS]: Izv. Akad. Nauk LatvSSR, no. 12, (149), 1959.

4. Liliyenberg, D.A., Nekotoryye voprosy oledeneniya Vostochnogo Kavkaza. [SOME PROBLEMS OF GLACIATION IN EASTERN KAZAKHSTAN]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

5. Liliyenberg, D.A., Osnovnyye cherty rel'yefa Dagestana. [CHIEF FEATURES OF THE RELIEF OF DAGESTAN]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

56. Lukashoy, K.I., Da pytannya ab klasifikatsii gipergennykh geakhimichnykh zon i pravintsyy. [AN ATTEMPT AT A CLASSIFICATION OF SUPERGENE GEOCHEMICAL ZONES AND PROVINCES (IN BELORUSSIAN)]: Vestsi Akad. Nauk BSSR, ser. giz.-tekhn. navuk, no. 4, 1959.

57. Lyalin, Yu.I., Vulkanogennaya svita verkhnego kembriya-tremadoka khrebta Chingiz. [A VOLCANOGENIC FORMATION IN THE UPPER CAMBRIAN-TREMADOCIAN DEPOSITS OF THE CHINGIZ RANGE]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

58. Mayev, Ye.G., Osobennosti osadkoobrazovaniya v Yuzhnom Kaspii. [SOME PECULIARITIES OF SEDIMENTATION IN THE SOUTHERN CASPIAN]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

59. Maksimova, N.S., and D.P. Naydin, O mezhdunarodnom stratigraficheskom slovare. [ON THE INTERNATIONAL DICTIONARY OF STRATIGRAPHY]: Sov. geol. no. 12, 1959.

60. Maruashvili, L.I., K voprosu o bol'shoy mezhlednikovoy epokhe pleystotsena. [ON THE PROBLEM OF THE GREAT PLEISTOCENE INTERGLACIAL EPOCH]: Botan. zh., Akad. Nauk SSSR, t. 44, no. 12, 1959.

61. Maslakova, N.I., Verkhnemelovyye otlozheniya Gornogo Kryma. [THE UPPER CRETACEOUS DEPOSITS OF THE MOUNTAIN AREA OF THE CRIMEA]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

62. Maslov, V.P., Izvestkovyye vodorosli kak ukazateli usloviy obrazovaniya osadka. [CALCAREOUS ALGAE AS INDICATORS OF THE CONDITIONS OF FORMATION OF THE SEDIMENT]: Sov. geol., no. 12, 1959.

63. Makhlayev, V.G., Tsiklichnost' stroyeniya dankovo-lebedyanskikh sloyev v tsentral'nom devonskom pole. [THE CYCLICAL NATURE OF THE STRUCTURE OF THE DANKOVO-LEBEDYANSKIYE BEDS IN THE CENTRAL DEVONIAN FIELD]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

64. Makhnach, A.S., and V.P. Kurachka, Stratygrafiya i litologiya eazembryyskikh i kembryyskikh adkladannyau vëski Kurantsa Vileyskaga rayena maladzechanskay i voblastsi. [THE STRATIGRAPHY AND LITHOLOGY OF THE PRECAMBRIAN AND CAMBRIAN DEPOSITS NEAR KURANETS IN THE VILEY DISTRICT OF MALADZECHAN AND THE SURROUNDING AREAS

(IN BELORUSSIAN)]: Vestsi. Akad. Nauk BSSR, ser. fiz.-tekhn. navuk, no. 4, 1959.

65. Milanovskiy, Ye. Ye., O sledakh verkhnepliotsenovogo oledeneniya v vysokogornoy chasti Tsentral'nogo Kavkaza. [ON THE TRACES OF LATE PLIOCENE GLACIATION IN THE HIGHLAND PART OF THE CENTRAL CAUCASUS]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

66. Mitsyanina, I.V., Stratygrafichnaya skhema yurskikh adkladannyau Belarusi. [THE STRATIGRAPHY OF THE JURASSIC DEPOSITS OF BELORUSSIA (IN BELORUSSIAN)]: Vestsi. Akad. Nauk BSSR, ser. fiz.-tekhn. navuk, no. 4, 1959.

67. Milanovskiy, Ye. Ye., O tektonike Tsentral'nogo Kavkaza. [THE TECTONICS OF THE CENTRAL CAUCASUS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

68. Mikhaylov, I.M., Osobennosti geologicheskogo kartirovaniya v Adyrnoy zone Yuzhnoy Fergany i svyaz' glubinnoy tektoniki s poverkhnost'yu. [SOME FEATURES OF GEOLOGIC MAPPING IN THE ADYR ZONE OF THE SOUTHERN FERGANA REGION AND THE RELATIONSHIP BETWEEN THE DEEP TECTONIC STRUCTURE AND THE SURFACE]: Novosti neft. tekhniki, geologiya, no. 12, 1959.

69. Muratov, M.V., O stratigrafii triasovykh i nizhneyurskikh otlozheniy Kryma. [THE STRATIGRAPHY OF THE TRIASSIC AND LOWER JURASSIC DEPOSITS OF THE CRIMEA]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

70. Nagibina, M.S. and V.N. Krestovnikov, Skhema stratigrafii paleozoyskikh otlozheniy okrestnostey goroda Zei. [A STRATIGRAPHIC SCHEME FOR THE PALEOZOIC DEPOSITS IN THE VICINITY OF THE CITY OF ZEYA]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

71. Nazarkin, L.A., O roli skorosti sedimentatsii v nakoplenii absolyutnykh mass organicheskogo veshchestva v osadke. [ON THE RATE OF SEDIMENTATION AS A FACTOR IN THE ACCUMULATION OF THE ABSOLUTE MASS OF ORGANIC MATTER IN SEDIMENTS]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

72. Akademik D.V. Nalivkin, Yubiley. [ACADEMICIAN D.V. NALIVKIN: JUBILEE ANNIVERSARY]: Sov. geol., no. 12, 1959.

73. Nikitina, L.G., Geologicheskoye stroyeniye devonskogo vulkanicheskogo apparata v gorakh mashan na Chingize. [THE GEOLOGY OF THE DEVONIAN VOLCANIC STRUCTURES IN THE MASHAN MOUNTAINS OF THE CHINGIZ RANGE]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

74. Nikolayev, N.I. i dr. O knige A.Ye. Mikhaylova "Osnovy strukturnoy geologii i geologicheskogo kartirovaniya". [ON A.Ye. MIKHAYLOV'S BOOK, "PRINCIPLES OF STRUCTURAL GEOLOGY AND GEOLOGIC MAPPING"]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

75. O deyatel'nosti geologicheskikh sektsiy Moskovskogo obshchestv ispytateley prirody. [ON THE ACTIVITIES OF THE GEOLOGICAL SECTION OF THE MOSCOW SOCIETY OF NATURAL SCIENTISTS] Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

76. Pak, V.A., Ritmostratigraficheskoye raschleneniye mollas Fergany po seysmorazvedochnym dannym. [A CYCLICAL STRATIGRAPHIC SUBDIVISION OF THE FERGANA MOLASSE DEPOSITS, BASED ON SEISMIC SURVEY DATA]: Uzb. geol. zh. no. 6, 1959.

77. Perfil'yev, Yu.S., Novyye dannyye po stratigrafii nizhnego paleozoya Gornogo Altaya. [NEW DATA ON THE STRATIGRAPHY OF THE LOWER PALEOZOIC DEPOSITS OF THE GORNYY ALTAY]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

78. Petrov, N.P., K geologii solevykh otlozheniy na yuge Sredney Azii. [THE GEOLOGY OF THE SALINE DEPOSITS IN THE SOUTH OF CENTRAL ASIA]: Uzb. geol. zh. no. 6, 1959.

79. Pecherskiy, D.M., Opyt vozrastnogo raschleneniya i vozrastnoy korrelyatsii effuzivov basseynov rek bol'shogo Anyuya i Omolona. [AN EXPERIMENT IN THE CHRONOLOGICAL SUBDIVISION AND CORRELATION OF THE EXTRUSIVES IN THE BASINS OF THE BOL'SHOY ANYUY AND OMOLON RIVERS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 12, 1959.

80. Pokrovskaya, I.M. and V.V. Zauyer, Palinologicheskoye obosnovaniye vozrasta yantarenosnykh otlozheniy Pribaltiki. [THE PALYNOLOGICAL BASIS FOR THE AGE OF THE AMBER-BEARING DEPOSITS OF THE BALTIC AREA]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

81. Popov, V.V., O monografii G.A. Mavlyanova "Geneticheskiye tipy lëssov i lëssovidnykh porod tsentral'noy i yuzhnoy chastey

Sredney Azii". Tashkent, 1958. [ON G. A. MAVLYANOV'S MONOGRAPH, "GENETIC TYPES OF LOESSES AND LOESSIAL ROCKS IN THE CENTRAL AND SOUTHERN PARTS OF CENTRAL ASIA"]: Uzb. geol. zh., no. 6, 1959.

. Poretskaya, Ye.S., Stratigraficheskoye i geograficheskoye rasprostraneniye nizhnetretichnykh morskikh yezhey Sredizemnomorskoy oblasti. [THE STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION OF THE LOWER TERTIARY MARINE SEA URCHINS OF THE MEDITERRANEAN REGION]: Vestn. LGU, no. 24, ser. geol. i geogr., vyp. 4, 1959.

. Pronicheva, M.V., O metodike i rezul'tatakh strukturno-geomorfologicheskikh issledovaniy v Aktyubinskom Priural'ye. [THE METHODS AND RESULTS OF STRUCTURAL-GEOMORPHOLOGICAL INVESTIGATIONS IN THE AKTYUBA AREA OF THE URALS REGION]: Novosti neft. tekhniki, geologiya, no. 12, 1959.

. Padchenko, M.I., Paleofitologicheskoye obosnovaniye stratigrafii karbona Kazakhstant. [THE PALEOPHYTOLOGICAL BASIS FOR THE CARBONIFEROUS STRATIGRAPHY OF KAZAKHSTAN]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 4(37) 1959.

. Razumova, V.N., Priroda krasnykh i zelenykh okrasok glinistykh porod nekotorykh krasnotsvetnykh aridnykh formatsiy. [THE NATURE OF THE RED AND GREEN COLORATION IN THE ARGILLACEOUS ROCKS OF CERTAIN RED-COLORED ARID FORMATIONS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

. Rastvorova, V.A., and Ye.I. Sakharova, Noveyshaya tektonika Bratskogo rayona. [THE RECENT TECTONICS OF THE BRATSK AREA]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

. Repina, L.N., and V.V. Khomentovskiy Stratigrafii nizhnego kemriya. [THE STRATIGRAPHY OF THE LOWER CAMBRIAN]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

. Resheniye Chetvertogo vsesoyuznogo litologicheskogo soveshchaniya, posvyashchennogo osadochnym formatsiyam i ikh fatsial'nomu analizu v svyazi s prognozom poleznykh iskopayemykh. [RESOLUTION OF THE FOURTH ALL-UNION LITHOLOGICAL CONFERENCE ON SEDIMENTARY FORMATIONS AND THEIR FACIES ANALYSIS FROM THE STANDPOINT OF FORECASTING THE OCCURRENCE OF ECONOMIC MINERALS]: Sov. geol. no. 12, 1959.

89. Reshit'ko, V.A., Metamorfism zon rasslantsevaniya i glubinnykh razlomov v rayone Kachkanarskogo gabbro-peridotitovogo massiva na Urale. [THE METAMORPHISM OF ZONES OF SCHIST FORMATION AND DEEP FAULTS IN THE AREA OF THE KACHKANAR GABBRO-PERIDOTITE MASSIF IN THE URALS]: Sov. geol., no. 12, 1959.

90. Lev Borisovich Rukhin. Nekrolog. [LEV BORISOVICH RUKHIN: OBITUARY]: Vestn. LGU, no. 24, ser. geol. i geogr., vyp. 4, 1959.

91. Ryzhkov, O.A., and Sh.D. Davlyatov, K tektonike pokrovnykh otlozheniy Zapadnogo Uzbekistana. [THE TECTONICS OF THE MANTLE DEPOSITS IN WESTERN UZBEKISTAN]: Doklady, Akad. Nauk UzSSR, no. 12, 1959.

92. Savochkina, Ye.N., Verkhneordovikskiy intruzivnyy kompleks Zapadnogo Tarbagataya. [THE UPPER ORDOVICIAN INTRUSIVE COMPLEX OF THE WESTERN TARBAGATAY]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

93. Samyshkina, K.G., Foraminifery i stratigrafiya al'bskikh otlozheniy Dagestana. [THE FORAMINIFERA AND STRATIGRAPHY OF THE ALBIAN DEPOSITS OF DAGESTAN]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

94. Seidov, A.G., Litologo-mineralogicheskaya kharakteristika glinistykh porod maykopskoy svity Lenkoranskoy oblasti Azerbaydzhana. [THE LITHOLOGY AND MINERALOGY OF THE ARGILLACEOUS ROCKS OF THE MAYKOPIAN FORMATION IN THE LENKORAN AREA OF AZERBAYDZHAN]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr., nauk, no. 6, 1959.

95. Selin, Yu.I., Novyye dannyye o faunisticheskoy kharakteristike oligotsenovykh otlozheniy Pridneprovskogo margantsevorudnogo basseyna. [NEW DATA ON THE FAUNAL CHARACTERISTICS OF THE OLIGOCENE DEPOSITS OF THE DNEPR MANGANESE-ORE BASIN]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

96. Starkov, N.P., and Ye.N. Larionova, Drevniye izliyaniya pikritovykh porfiritov na territorii Permskoy oblasti. [ANCIENT PICRITIC PORPHYRITE FLOWS IN THE PERM REGION]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

97. Suvorov, A.I., K voprosi o skladchatoglybovykh strukturakh i o primenyayemykh k nim ponyatiyakh i terminakh. [ON THE PROBLEM OF BLOCK-FOLDED STRUCTURES

AND THE CONCEPTIONS AND TERMS APPLIED TO THEM]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

98. Sultanov, A.D., and G.K. Abdullayev, Litologiya i kollektorskiye svoystva porod verkhney chasti produktivnoy tolshchi Prikurinskoy nizmennosti. [THE LITHOLOGY AND RESERVOIR PROPERTIES OF THE ROCKS IN THE UPPER PART OF THE OIL-PRODUCING STRATA OF THE KURA LOWLAND]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

99. Skhirtladze, N.I., Novyye dannyye o verkhnem paleozoye Khramskogo massiva. [NEW DATA ON THE UPPER PALEOZOIC OF THE KHRAMSKIY MASSIF]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

100. Tamrazyan, G.P., Bakinskiy glubinnyy val. [THE DEEP ELONGATED UPLIFT OF BAKU]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 12, 1959.

101. Tatarskiy, V.B., O nomenklature i klassifikatsii karbonatnogo materiala po razmeru zeren. [THE NOMENCLATURE AND CLASSIFICATION OF CARBONATE MATERIAL ACCORDING TO GRAIN SIZE]: Vestn LGU, no. 24, ser. geol. i geogr., vyp. 4, 1959.

102. Til'man, S.M., and G.M. Sosunov, Nekotoryye osobennosti razvitiya Chukotskoy geosinklinal'noy zony v nizhnem triase. [SOME SPECIAL FEATURES OF THE DEVELOPMENT OF THE CHUKOTKA GEOSYNCLINAL ZONE IN THE EARLY TRIASSIC]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

103. Tikhonov, V.I., and G.B. Udintsev, K voprosu o svyazyakh mezhdu tektonikoy Kamchatki i rel'yefom yeye podvodnykh sklonov. [ON THE RELATIONSHIPS BETWEEN THE TECTONICS OF KAMCHATKA AND THE RELIEF OF ITS SUBMARINE SLOPES]: Doklady, Akad. Nauk, SSSR, t. 130, no. 3.

104. Ulomov, V.I., Nekotoryye osobennosti stroyeniya zemnoy kory Sredney Azii po sapisyam moshchnogo vzryva. [SOME PECULIARITIES IN THE STRUCTURE OF THE EARTH'S CRUST, IN CENTRAL ASIA, AS INTERPRETED FROM THE RECORDING OF A POWERFUL EXPLOSION]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 1.

105. Utrobin, V.N., Osnovnyye cherty morfologii, gipsometrii i genezisa dotretichnoy poverknosti vneshey zony Predkarpatskogo progiba i yugo-zapadnoy okrainy Russkoy platformy. [MAIN FEATURES OF THE MORPHOLOGY, HYPSOMETRY AND GENESIS OF THE PRE-TERTIARY SURFACE OF THE OUTER ZONE OF THE CISCARPATHIAN BASIN AND THE SOUTHWESTERN MARGIN OF THE RUSSIAN PLATFORM]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

106. Ushakov, S.A., and G.E. Lazarev, Moshchnost' zemnoy kory po meridional'nomu profilyu morya Deyvisa-Stantsiya Pionerskaya. [THE THICKNESS OF THE EARTH CRUST ALONG A MERIODIONAL PROFILE FROM THE DAVIS SEA TO THE PIONERSKAYA STATION IN THE ANTARCTIC]: Inform. byul. Sov. Antarkt. eksp., no. 11, 1959.

107. Khalafova, R.A., Verkhnesenonskiye otlozheniya severo-zapadnoy chasti Nakhichevanskoy ASSR. [THE UPPER SENONIAN DEPOSITS IN THE NORTHWESTERN PART OF THE NAKHICHEVAN ASSR]: Izv. vyssh. uchebn. zaved., ser. Izv. vyssh. uchebn. zaved., ser. neft' i gaz, no. 1.

108. Khalymbadzha, V.G., Otlozheniya bashkirskogo yarusa tsentral'nykh i severnykh rayonov Tatarii. [THE DEPOSITS OF THE BASHKIRIAN STAGE IN THE CENTRAL AND NORTHERN PARTS OF TATARIYA]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

109. Chaykovskaya, E.V., K voprosu karbonatnykh neftematerinskikh otlozheniy Turukhanskogo i Noril'skogo rayonov. [THE CARBONATE OIL-CONTAINING DEPOSITS OF THE TURUKHANSK AND NORIL'SK DISTRICTS]: Izv. vyssh. ucheb. zaved., ser. neft i gaz, no. 1.

110. Chudinov, Yu.V., O dugoobraznoy zonal'nosti v geologicheskom stroyenii Vostochnoy Tuvy i smezhnykh oblastey. [THE ACURATE ZONALITY IN THE GEOLOGIC STRUCTURE OF EASTERN TUVA AND THE ADJACENT REGIONS]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

111. Shevchenko, V.I., Granitsa devona i karbona v Stalingradskom pravoberezh'ye Volgi. [THE DEVONIAN-CARBONIFEROUS BOUNDARY IN THE STALINGRAD AREA ON THE RIGHT BANK OF THE VOLGA RIVER]: Geol. nefti i gaza, no. 1.

112. Shcherba, G.N., and A.I. Ivanov, O vozraste nekotorykh gertsinskikh intruzivnykh kompleksov Tsentral'nogo Kazakhstana. [THE AGE OF SOME HERCYNIAN INTRUSIVE COMPLEXES OF CENTRAL KAZAKHSTAN]: Vestn. Akad. Nauk KazSSR, no. 12, 1959.

13. Ez, V.V., O tektonicheskikh osobennostyakh oblasti vozniknoveniya glubokofokusnykh zemletryaseniy v Vostochnykh Karpatakh. [THE TECTONIC FEATURES OF THE AREAS OF DEEP-FOCUS EARTHQUAKES IN THE EASTERN CARPATHIANS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 12, 1959.

14. Ez, V.V., Eksperimental'noye vosproizvedeniye skladchatoy struktury so skladkami raznoobraznykh prostiraniy. [THE EXPERIMENTAL REPRODUCTION OF FOLDED STRUCTURES WITH FOLDS TRENDING IN VARIOUS DIRECTIONS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

PALEONTOLOGY

15. Barskaya, V.F., Drevneyshiye khalizitidy Tsentral'nogo Taymyra. [THE OLDEST CHALIZITHIDS OF THE CENTRAL TAYMYR REGION]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

16. Vologdin, A.G., Novyye dannyye po arkheotsiatam Sibiri. [NEW DATA ON THE ARCHEOCYATHIDS OF SIBERIA]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

17. Vologdin, A.G., O rode Ajacicyathus Bedford et bedford, 1930, i sem. Ajacicyathidae Bodford et betford, 1939. [ON THE GENUS AJACICYATHUS BEDFORD ET BEDFORD, 1930, AND THE FAMILY AJACICYATHIDAE]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

18. Gabuniya, L.K., and O. Iliyesku, O pervoy nakhodke ostatkov gigantskikh nosorogov iz sem. Indricotheriidae v Rumynii. [THE FIRST OCCURRENCE OF REMAINS OF GIANT RHINOCEROSES OF THE FAMILY INDRICOTHERIIDAE IN RUMANIA]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

19. Dzhabarova, Kh.S., Nekotoryye dannyye o verkhnemiotsenovoy rastitel'nosti po dannym sporovo-pyl'tsevogo analiza rayona Yalama (Azerbaydzhan). [SOME INFORMATION ON LATE MIOCENE VEGETATION, BASED ON SPORE-POLLEN ANALYSIS IN THE YALAMA AREA (AZERBAYDZHAN)]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 12, 1959.

20. Doludenko, M.P., O stroyenii iskopayemykh spor Coniopteris. [ON THE STRUCTURE OF THE FOSSIL SPORES OF CONIOPTERIS]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

21. Dorofeyev, P.I., O novykh vidakh Azolla Lam. dlya tretichnoy flory SSSR. [NEW SPECIES OF AZOLLA LAM. IN THE TERTIARY FLORA OF THE USSR]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 12, 1959.

122. Drushchits, V.V., Retsenziya na uchebnik "Paleontologiya bespozvonochnykh". Pod red. Yu.A. Orlova, i dr. [A REVIEW OF THE TEXTBOOK, "INVERTEBRATE PALEONTOLOGY", EDITED BY YU.A. ORLOV ET AL.]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

123. Ivanovskiy, A.B., and L.Ya. Lavrova, Nakhodki ostatkov shestiluchevykh korallov v melovykh i paleogenovykh otlozheniyakh Zapadno-Sibirskoy nizmennosti. [OCCURRENCES OF SCLERACTINIAN CORAL REMAINS IN THE CRETACEOUS AND PALEOGENE DEPOSITS OF THE WESTERN SIBERIAN LOWLAND]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

124. Krasnopeyeva, P.S., Arkheotsiaty ger Agyrek Pavlodarskoy oblasti Kazakhskoy SSSR. [ARCHEOCYATHIDS OF THE AGYREK MOUNTAINS IN THE PAVLODAR REGION OF THE KAZAKH SSR]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

125. Kuchuloriya, N.D., Ob usloviyakh obitaniya fauny v Akhaltsikhskom verkhneeotsenovom basseyne. [ECOLOGICAL CONDITIONS OF THE FAUNA IN THE LATE EOCENE AKHALTSIKH BASIN]: Vestn. LGU, ser. geol. i geogr., no. 24 (vyp. 4), 1959.

126. Kushnar', L.V., Dvustvorchatyye mollyuski verkhnego paleozoya Yuzhnoy Fergany i ikh stratigraficheskoye znacheniye. [DIMYARIAN MOLLUSCS OF THE UPPER PALEOZOIC IN THE SOUTHER FERGANA AND THEIR STRATIGRAPHIC SIGNIFICANCE]: Vestn. LGU, no. 24, ser. geol. i geogr., vyp. 4, 1959.

127. Leleshus, V.L., K diagnozu siluriyskikh tabulyat iz roda Cylindrostylus Sokolov. [ON THE IDENTIFICATION OF THE SILURIAN TABULATE CORALS OF THE GENUS CYLINDROSTYLUS SOKOLOV]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

128. Sukachev, V.N., et al. K istorii razvitiya rastitelnogo pokrova tsentral'nykh oblastey Russkoy ravniny v techeniye golotsena. [ON THE DEVELOPMENT OF THE VEGETATIVE COVER OF THE CENTRAL REGIONS OF THE RUSSIAN PLAIN DURING THE HOLOCENE]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

129. Khalilov, D.M., Novyye vidy foraminifer valanzhin-goterivskikh otlozheniy

severo-vostochnogo Azerbaydzhana. [NEW SPECIES OF FORAMINIFERA FROM THE VALANGINIAN-HAUTERIVIAN DEPOSITS OF NORTHEASTERN AZERBAYDZHAN]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

130. Khokhlov, E.P., and N.G. Osipov, Ob otkrytii devonskoy fauny v basseyne r. Nilana (Khabarovskiy kray). [ON THE DISCOVERY OF DEVONIAN FAUNA IN THE NILAN RIVER BASIN (KHABAROV DISTRICT)]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

131. Khokhryakov, A.P., Novyye mestonakhozhdeniya reliktovoy izvestnyakovoy flory na Srednem Urale. [NEW OCCURRENCES OF RELICT CALCAREOUS FLORA IN THE MIDDLE URALS]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 12, 1959.

132. Chochiyeva, K.I., Novyy vid Heracleum iz chaudinskikh otlozheniy Gurii. [A NEW SPECIES OF HERACLEUM FROM THE CHAUDA DEPOSITS OF GURIYA]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

133. Shchaglova, V.V., and B.V. Shavyakou, Ab znakhodtsy u Belarusi reshtkau mamanta u adkladannyakh ryskaga uzrostu. [THE DISCOVERY OF MAMMOTH REMAINS IN BELORUSSIA IN DEPOSITS OF THE RUSSIAN PLAIN (IN BELORUSSIAN)]: Vestsi. Akad. Nauk BSSR, ser. fi.-tekhn. navuk, no. 4, 1959.

PETROGRAPHY, MINERALOGY, CRYSTALLOGRAPHY, GEOCHEMISTRY

134. Agafonova, T.N., and A.Ye. Rol', Fersmana v razvitii kristallokhimii. [THE ROLE PLAYED BY A.YE. FERSMAN IN THE DEVELOPMENT OF CRYSTALLOCHEMISTRY]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

135. Alekseyev, F.A., and R.A. Rezvanov, Aktivatsionnyy analiz gornykh porod v usloviyakh skvazhin. [ACTIVATION ANALYSIS OF ROCKS IN DRILL HOLES]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

136. Aleksina, I.A., O raspredelenii autigennogo kremnezema v ilistykh osadakh sredney chasti Kaspiyskogo morya. [THE DISTRIBUTION OF AUTHIGENIC SILICA IN THE OOZE SEDIMENTS OF THE CENTRAL PART OF THE CASPIAN SEA]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

137. Ankinovich, Ye.A., and N.I. Silant'yeva, Gorseyksit iz glinisto-antraksolitovykh vanadiyenosnykh slantsev Kazakhstana [GORCEIXITE FROM THE ARGILLACEOUS ANTHRAXOLITIC VANADIUM-BEARING SHALES OF KAZAKHSTAN]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

138. Berlin, T.S., and A.V. Khabakov, Issledovaniye nekotorykh fiziko-khimicheskikh svoystv karbonatnykh porod s tsel'yu opredeleniya usloviy ikh obrazovaniya. [AN INVESTIGATION OF SOME PHYSICO-CHEMICAL PROPERTIES OF CARBONATE ROCKS IN ORDER TO DETERMINE THE CONDITIONS OF THEIR FORMATION]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

139. Betekhtin, A.G., and G.A. Sokolov, K shestidesyatiletiyu akademika D.S. Korzhinskogo. [ON THE OCCASION OF THE SIXTIETH ANNIVERSARY OF ACADEMICIAN D.S. KORZHINSKIY]: Geol. rudn. mestorozhd., no. 6, 1959.

140. Borovskiy, I.B., A.N. Deyev and I.D. Marchukova, Primeneniye metoda lokal'nogo rentgenospektral-nogo analiza k issledovaniyu mineralov platinovoy gruppy. [THE APPLICATION OF THE METHOD OF LOCAL X-RAY SPECTROGRAPHIC ANALYSIS TO THE STUDY OF MINERALS OF THE PLATINUM GROUP]: Geol. rudn. mestorzhd., no. 6, 1959.

141. Braunell, D.M., Pribor dlya opredeleniya berilliya v polevykh usloviyakh. [AN INSTRUMENT FOR DETERMINING BERYLLIUM UNDER FIELD CONDITIONS]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 7(24), 1959.

142. Buturlinov, N.V., O lamprofirakh Shakhtinskogo rayona. [ON THE LAMPROPHYRES OF THE SHAKHTA AREA]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

143. Veber, V.V., S.G. Sarkisyan and A.I. Gorskaya, Donnyye osadki oz. Sevan i osobennosti ikh organicheskogo veshchestva. [THE BOTTOM SEDIMENTS OF LAKE SEVAN AND SOME PECULIARITIES OF THEIR ORGANIC MATTER]: Geol. nefti i gaza, no. 1.

144. Veber, V.V., and V.A. Uspenskiy, Kobystanskiy kerit v ryadu drugikh bitumov Yugo-Vostochnogo Kavkaza. [THE KOBYSTAN KERITE IN THE SERIES OF OTHER SOLID BITUMENS OF THE SOUTHEASTERN CAUCASUS]: Sov. geol., no. 12, 1959.

145. Vikulova, M.F., Issledovaniye smesey glinistykh mineralov. [THE STUDY OF CLAY MINERAL MIXTURES]: Doklady, Akad. Nauk SSSR, t. 130, no. 1.

146. Voskresenskiy, P.I., Beskislotnyye metody razlozheniya rud i mineralov pri provedenii analiticheskikh reaktsiy mezhdu tverdymi veshchestvami. [NON-ACIDIC METHODS OF DISSOLVING ORES AND MINERALS IN PRODUCING ANALYTICAL REACTIONS BETWEEN SOLID SUBSTANCES]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 7(24), 1959.

147. Galyuk, V.A., Granaty grossulyar-andraitovogo sostava iz flogopitovykh mestorozhdeniy timptonskoy gruppy (Yuzhnaya Yakutiya). [GARNETS OF GROSSULARITE-ANDRADITE COMPOSITION FROM THE PHLOGOPITE DEPOSITS OF THE TIMPTON GROUP (SOUTHERN YAKUTIYA]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

148. Genkin, A.D., Usloviya nakhozhdeniya i osobennosti sostava mineralov platinovoy gruppy v rudakh Noril'skogo mestorozhdeniya. [THE CONDITIONS OF OCCURRENCE AND SOME FEATURES OF THE COMPOSITION OF MINERALS OF THE PLATINUM GROUP IN THE ORES OF THE NORIL'SK DEPOSIT]: Geol. rudn. mestorozhd., no. 6, 1959.

149. Gerkhardt, L.I., Ekstraktsionno-kolorimetricheskiy mikrometod opredeleniya toriya v rudakh i mineralakh. [AN EXTRACTION-COLORIMETRIC MICROMETHOD OF DETERMINING THORIUM IN ORES AND MINERALS]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 7(24), 1959.

150. Ginzburg, I.V., K razvitiyu nashikh predstavleniy o ponyatii "shchelochnoy granit". [ON THE DEVELOPMENT OF OUR UNDERSTANDING OF THE CONCEPT, "ALKALINE GRANITE"]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

151. Golovanov, I.M., Koronadit iz zony okisleniya svintsovo-tsinkovogo mestorozhdeniya Kurgashinkan (UzSSR). [CORONADITE FROM THE OXIDE ZONE OF THE KURGASHINKAN LEAD-ZINC DEPOSIT (UzSSR)]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

152. Golovko, V.A., Nekotoryye dannyye k petrograficheskoy i geokhimicheskoy kharakteristike ozerskokhovanskikh otlozheniy Podmoskov'ya. [SOME DATA ON THE PETROGRAPHIC AND GEOCHEMICAL NATURE OF THE OZERSKKHOVAN DEPOSITS OF THE MOSCOW BASIN AREA]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

153. Gorbunova, L.I., Glaukonit nizhnemelovykh otlozheniy Dagestana. [GLAUCONITE FROM THE LOWER CRETACEOUS DEPOSITS OF DAGESTAN]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

154. Dianov-Klokov, V.I., Izmeritel' maloy ostatochnoy namagnichennosti gornykh porod. [A DEVICE FOR MEASURING LOW RESIDUAL MAGNETIZATION IN ROCKS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 1.

155. Distanova, A.N., O kontaktovykh yaleniyakh na primere nekotorykh granitnykh intruziy Tsentral'nogo Kazakhstana. [CONTACT PHENOMENA AS SEEN IN THE EXAMPLE OF SOME GRANITIC INTRUSIVES OF CENTRAL KAZAKHSTAN]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

156. Dmitriyev, Yu.I. Trappovyy magmatizm i genezis islandskogo shpata r. Chony. [TRAPROCK IGNEOUS ACTIVITY AND THE GENESIS OF THE ICELAND SPAR ON THE CHONA RIVER]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

157. Dneprovskiy, I.S., Novyye izotopy erbiya i tol'miya. [NEW ISOTOPES OF ERBIUM AND HOLMIUM]: Atomnaya energiya, t. 8, vyp. 1.

158. Durov, S.A., Dz.M. Pkhalagova, T.I. Drobasheva and R.I. Frolova, Okisleniye sul'fida serebra kak prichina udaleniya iona khlora iz vody gornykh rek Tsentral'nogo Kavkaza. [THE OXIDATION OF SILVER SULFIDE AS THE REASON FOR THE REMOVAL OF CHLORINE ION FROM THE WATERS OF THE MOUNTAIN RIVERS OF THE CENTRAL CAUCASUS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

159. Yevdokhin, A.G., Opyt vozrastnoy korrelyatsii granitoidnykh porod po elementam-primesyam v biotitakh. [AN EXPERIMENT IN THE CHRONOLOGICAL CORRELATION OF GRANITOID ROCKS BY THE ELEMENTS PRESENT AS ADMIXTURES IN BIOTITES]: Byul. nauch.-tekhn. inform. M-va geol. i okhrani nedr., SSSR, no. 7(24), 1959.

160. Yemel'yanenko, P.F., Mezozoyskiye bazal'ty i dolerity r. Ishima (Severnyy Kazakhstan). [THE MESOZOIC BASALTS AND DOLERITES OF THE ISHIM RIVER (NORTHERN KAZAKHSTAN)]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

161. Zhizhchenko, B.P., Osnovnyye resul'taty kompleksnogo biogeokhimicheskogo izucheniya tretichnykh otlozheniy Tsentral'nogo i Vostochnogo Predkavkaz'ya. [THE CHIEF RESULTS OF A COMPLEX BIOGEOCHEMICAL STUDY

OF THE TERTIARY DEPOSITS OF THE CENTRAL AND EASTERN CISCAUCASUS]: Geol. nefti i gaza, no. 1.

162. Zaborenko, K. B., A. M. Babeshkin and I. V. Kovalenko, Izucheniye emanirovaniya i vyshchelachivaniya izotopov radiya iz monatsita. [A STUDY OF THE EMANATION AND LEACHING OF RADIUM ISOTOPES FROM MONAZITE]: Radiokhimiya, t. 1, vyp. 6, 1959.

163. Zaborenko, K. B., A. M. Babeshkin and I. S. Aul'chenko, Mekhanizm nakopleniya i vydeleniya atomov otdachi v sistemakh tverdaya faza-gaz. tverdaya faza-rastvor. [THE MECHANICS OF ACCUMULATION AND SEGREGATION OF RECOIL ATOMS IN SOLID PHASE—GAS AND SOLID PHASE—SOLUTION SYSTEMS]: Radiokhimiya, t. 1, vyp. 6, 1959.

164. Zaykovskiy, F. V., Novyye tsvetnyye reaktsii na selen. [NEW SELENIUM COLOR REACTIONS]: Byul. nauch.-tekhn. inform. M-va geol. i okhrani nedr SSSR, no. 6(23), 1959.

165. Zvyagintsev, O. Ye., and V. I. Shamayev, Primenen'ye radioktivatsionnogo analiza dlya opredeleniya mikroprimesey v tellure. [THE USE OF RADIOACTIVATION ANALYSIS IN DETERMINING MICROADMIXTURES IN TELLURIUM]: Radiokhimiya, t. 1, byp. 6, 1959.

166. Ivankin, P. F., P. V. Inshin, V. S. Kuzebnyy and P. G. Vedernikov, O "dobatolitovykh" porfirovykh intruzivakh Rudnogo Altaya i ikh rudonosnosti. [ON THE "PRE-BATHOLITHIC" PORPHYRITIC INTRUSIVES OF THE RUDNYY ALTAY AND THEIR ORE CONTENT]: Doklady, Akad. Nauk SSSR, t, 130, no. 2.

167. Ivanov, V. V., and V. Yu. Volgin, Novyye dannyye o prirodnykh kontsentratsiyakh indiya. [NEW DATA ON NATURAL CONCENTRATIONS OF INDIUM]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

168. Ikornikova, N. Yu., Kristallizatsiya magnetita i obrazovaniye uglevodorodov v sisteme $CaCO_3$-NaCl-H_2O-Fe pri vysokikh temperaturakh i davleniyakh. [THE CRYSTALLIZATION OF MAGNETITE AND THE FORMATION OF HYDROCARBONS IN THE SYSTEM $CaCO_3$-NaCl-H_2O-Fe AT HIGH TEMPERATURES AND PRESSURES]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

169. Ismailov, Mil., Mineralogo-geokhimicheskaya kharakteristika i usloviya obrazovaniya rudoproyavleniya Nakpay (Almalykskiy rayon). [THE MINERALOGICAL-GEOCHEMICAL CHARACTERISTICS AND THE CONDITIONS OF FORMATION OF THE NAKPAY ORE OCCURRENCES (ALMALYK DISTRICT)]: Uzb. geol. zh., no. 6, 1959.

170. Kagner, M. N., Sostav i svoystva lentochnykh glin Severo-Zapada Rossii. [THE COMPOSITION AND PROPERTIES OF THE LENTICULAR CLAYS IN NORTHWESTERN RUSSIA]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

171. Kazenkina, G. A., O mineralom sostave sovremennykh osadkov zaliva Proval. [ON THE MINERAL COMPOSITION OF THE MODERN CLAYS IN THE GULF OF PROVAL]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

172. Kazitsyn, Yu. V., and G. V. Aleksandrov, O metasomaticheskoy zonal'nosti pri argillizatsii granit-porfirov okolo rudnykh tel. [THE METASOMATIC ZONALITY IN THE ARGILLIZATION OF THE GRANITE PORPHYRIES AROUND ORE BODIES]: Geol. rudn. mestorozhd., no. 5, 1959.

173. Kalinko, M. K., Opredeleniye granulometricheskogo sostava terrigennykh tyazhelykh mineralov kak odin iz metodov vyyasneniya putey ikh migratsii. [DETERMINATION OF THE GRANULOMETRIC COMPOSITION OF TERRIGENOUS HEAVY MINERALS AS ONE METHOD OF DISCOVERING THEIR MIGRATION PATHS]: Sov. geol., no. 12, 1959.

174. Karpov, R. V., Pegmatity osnovnykh porod monchetundry i svyazannoye s nimi sul'fidnoye orudeneniye. [THE PAGMATITES OF THE MONCHETUNDRA BASIC ROCKS AND THE SULFIDE MINERALIZATION ASSOCIATED WITH THEM]: Geol. rudn. mestorozhd., no. 5, 1959.

175. Kashkay, M. A., and I. A. Babayev, Fizikokhimicheskaya kharakteristika alunita i yego kolichestvenno-mineralogicheskiy podschet. [THE PHYSICOCHEMICAL PROPERTIES OF ALUNITE AND ITS QUANTITATIVE MINERALOGICAL COMPUTATION]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

176. Kerimov, G. G., Vtorichnyye kvartsity Kedabekskogo rayona. [THE SECONDARY QUARTZITES OF THE KEDABEK DISTRICT]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

177. Kol'bakh, V. I., K voprosu o metodike kolichestvennogo opredeleniya sillimanita, rutila, i pirita v sillimanitovykh rudakh.

[ON THE METHOD OF QUANTITATIVE DETERMINATION OF SILLIMANITE, RUTILE AND PYRITE IN SILLIMANITE ORES]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

8. Kononova, V.A., O metamiktnoy rasnovidnosti vezuviana iz shchelochnogo pegmatita Yugo-Vostochnoy Tuvy. [A METAMICT VARIETY OF VESUVIANITE FROM AN ALKALINE PEGMATITE IN SOUTHEASTERN TUVA]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

9. Kots, G.A., and V.D. Rozhkov, Malogabritnaya apparatura dlya separatsii mineralogicheskikh prob obogatitel'nymi metodami. [A COMPACT APPARATUS FOR THE SEPARATION OF MINERAL SAMPLES BY BENEFICIATION METHODS]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 7(24), 1959.

30. Kuzhel'nyy, N.M., Zamechaniya po stat'ye M.A. Abdulkabirovoy "Toriy v nekotorykh granitoidakh Kalby i Altaya". [SOME REMARKS ON M.A. ABDULKABIROVVA'S ARTICLE, "THE THORIUM IN CERTAIN GRANITOIDS OF KALBA AND THE ALTAY"]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

31. Kul'chitskiy, L.I., Metodika opredeleniya yemkosti pogloshcheniya glin s pomoshch'yu organicheskikh krasiteley. [A METHOD OF DETERMINING THE ABSORPTION CAPACITIES OF CLAYS BY MEANS OF ORGANIC COLORING AGENTS]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 7(24), 1959.

82. Liogen'kiy, S.Ya., Fizicheskiye svoystva pegmatitov i vmeshchayushchikh porod Karelii i Kol'skogo poluostrova. [THE PHYSICAL PROPERTIES OF THE PEGMATITES AND SURROUNDING ROCKS IN KARELIYA AND THE KOLA PENINSULA]: Geol. rudn. mestorozhd., no. 6, 1959.

83. Lukashev, K.I., and I.A. Dobrovol'skaya, Khimicheskiy sostav lëssovykh porod Belorussii. [THE CHEMICAL COMPOSITION OF THE LOESSIAL ROCKS IN BELORUSSIA]: Doklady, Akad. Nauk BSSR, t. 4, no. 1.

84. Mal'kova, R.N., Vulkanogennyye porody rudnogo polya Dzhanet. [THE VOLCANOGENIC ROCKS OF THE DZHANET ORE FIELD]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 4(37), 1959.

85. Malyshev, A.G., Po povody stat'i M.A. Abdulkabirovoy "Toriy v nekotorykh granitoidakh Kalby i Altaya". [ON THE SUBJECT OF M.A. ABDULKABIROVA'S ARTICLE "THE THORIUM IN CERTAIN GRANITOIDS OF KALBA AND THE ALTAY"]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

186. Malyshek, V.T., Magnitnyye shariki v nizhnetretichnykh obrazovaniyakh yuzhnogo sklona Severo-Zapadnogo Kavkaza. [MAGNETIC GLOBULES IN THE LOWER TERTIARY FORMATIONS ON THE SOUTHERN SLOPES OF THE NORTHWESTERN CAUCAUCASUS]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

187. Mirzayeva, K.Kh., K voprosu o soderzhanii margantsa i yego form v severnykh obyknovennykh i tipichnykh serozemakh. [THE PROBLEM OF THE CONTENT OF MANGANESE AND ITS FORMS IN THE ORDINARY AND TYPICAL NORTHERN SEROZEMS]: Doklady, Akad. Nauk UzSSR, no. 12, 1959.

188. Mukanov, K.M., L.F. Narkelyun and T.A. Yakovlevskaya, O nakhodke betekhtinita na Dzhezkazganskom mestorozhdenii. [ON THE DISCOVERY OF BETEKHTINITE IN THE DZHEZKAZGAN DEPOSIT]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

189. Nazarenko, M.F., O mekhanizme mineralizuyushchego vliyaniya dobavok na protsess mullitizatsii. [THE MECHANICS OF THE MINERALIZING EFFECT OF ADDITIVES ON THE PROCESS OF MULLITIZATION]: Vestn. Akad. Nauk KazSSR, no. 12, 1959.

190. Nazarov, Yu.I., Osobennosti otlozheniya barita i sul'fidov tsvetnykh metallov v mestorozhdenii Madneuli. [SOME FEATURES OF THE DEPOSITION OF BARITE AND NON-FERROUS METAL SULFIDES IN THE MADNEULI DEPOSIT]: Geol. rudn. mestorozhd., no. 6, 1959.

191. Omel'yanenko, B.I., Referat stat'i D. Millera i L. Kul'pa "Izucheniye izotopnogo sostava pud plato Kolorado". [A REVIEW OF THE ARTICLE BY D. MILLER AND L. KULP, "A STUDY OF THE ISOTOPE COMPOSITION OF THE ORES OF THE COLORADO PLATEAU"]: Geol. rudn. mestorozhd., no. 5, 1959.

192. Parkhomenko, E.I., Issledovaniye p'yezoelektricheskogo effekta gornykh porod i vozmozhnost' yego ispol'zovaniya v geologii. [AN INVESTIGATION OF THE PIEZOELECTRIC EFFECT OF ROCKS AND THE POSSIBILITIES FOR ITS UTILIZATION IN GEOLOGY]: Sov., geol., no. 12, 1959.

193. Pirozhnikov, L.P., Elementy-primesi v allotigennykh muskovitakh s ostrovov Champ, Viner-Neyshtadt i Kheysa (arkhipelag Zemlya Frantsa-Iosifa). [ELEMENTS PRESENT AS ADMIXTURES IN ALLOTHIGENIC MUSCOVITES FROM THE ISLANDS OF TSCHAMP, WIENER NEUSTADT AND HEISS (FRANZ JOSEF ARCHIPELAGO)]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

194. Ponomarev, V.D., and Ye.V. Margulis, K voprosu o povedenii khal'kopirita pri ok islitel'nom obzhige. [THE PROBLEM OF THE BEHAVIOR OF CHALCOPYRITE IN THE OXIDIZING FLAME]: Vestn. Akad. Nauk KazSSR, no. 11, 1959.

195. Pospelova, G.A., Prichiny obratnoy namagnichennosti vulkanogennykh porod Armenii i kuril'skikh ostrovov. [THE CAUSES OF THE REVERSE MAGNETIZATION OF THE VOLCANOGENIC ROCKS OF ARMENIA AND THE KURILE ISLANDS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 1.

196. Putalova, R.V., Nekotoryye dannyye o zameshchenii il'menita rutilom i anatazom. [SOME DATA ON THE REPLACEMENT OF ILMENITE BY RUTILE AND ANATASE]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

197. Ravikovich, Kh.A., Voprosy podzemnogo okisleniya uglevodorodov. [PROBLEMS OF THE UNDERGROUND OXIDATION OF HYDROCARBONS]: Geol. nefti i gaza, no. 1.

198. Radzhabov, M.N., and K.A. Ismaylov, O zhil'nykh porodakh Gornogo Talysha. [THE VEIN ROCKS OF THE GORNYY TALYSH]: Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

199. Ratynskiy, V.N., and L.E. Shterenberg, O svyazi germaniya s petrograficheskimi komponentami i skopayemykh ugley. [THE CONNECTION BETWEEN GERMANIUM AND THE PETROGRAPHIC COMPONENTS OF FOSSIL COALS]: Doklady Akad. Nauk SSSR, t. 130, no. 1.

200. Rozentsvit, A.O., Gidrotermal'naya argillizatsiya porod v Vostochnom Zabaykal'ye. [HYDROTHERMAL ARGILLIZATION OF THE ROCKS IN THE EASTERN TRANSBAYKAL]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

201. Romanova, M.A., Spektral'naya yarkost' peskov Yugo-Vostochnykh Karakumov. [THE SPECTROGRAPHIC BRIGHTNESS OF THE SANDS OF THE SOUTHEASTERN KARAKUMY]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

202. Seidov, A.G., K mineralogii glin maykop-skoy svity Kobystanskoy oblasti. [THE MINERALOGY OF THE CLAYS IN THE MAYKOPIAN FORMATION IN THE KOBY-STAN REGION]: Izv. Akad. Nauk AzerbSSR ser. geol.-geogr. nauk, no. 6, 1959.

203. Senchilo, N.P., Struktury i tekstury zhil'-nogo kvartsa redkometal'nykh shtokverkov Tsentral'nogo Kazakhstana. [THE STRUCTURES AND TEXTURES OF THE VEIN QUARTZ IN THE RARE-METAL STOCKWORK DEPOSITS OF CENTRAL KAZAKHSTAN]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 4(37), 1959.

204. Skornyakova, N.S., Margantsovyye konkretsii v osadkakh severo-vostochnoy chasti Tikhogo okeana. [MANGANESE CONCRETIONS IN THE BOTTOM SEDIMENTS OF THE NORTHEASTERN PART OF THE PACIFIC OCEAN]: Doklady, Akad. Nauk, SSSR, t. 130, no. 3.

205. Slavin, P.S., Formy zheleza v melovykh i tretichnykh otlozheniyakh Turkmenii. [THE FORMS OF IRON IN THE CRETACEOUS AND TERTIARY DEPOSITS OF TURKMENIA]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

206. Sokhen, M.N., Izgotovleniye etalonov dlya opredeleniya magnitnoy vospriimchivosti v obraztsakh. [THE PREPARATION OF STANDARD SAMPLES FOR DETERMINING THE MAGNETIC SUSCEPTIBILITY OF ROCK SPECIMENS]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr. SSSR, no. 6(23), 1959.

207. Udovkina, N.G., O smaragdite iz Polyarnogo Urala. [SMARAGDITE FROM THE POLAR URALS]: Doklady, Akad. Nauk SSSR, t. 130, no. 3.

208. Feoktistov, G.D., Chunskiy diabazovyy sill. [THE CHUN DIABASE SILL]: Doklady, Akad. Nauk SSSR, t. 130, no. 2.

209. Shatskaya, Z.I., Fotokolorimetricheskiy metod opredeleniya tsirkoniya. [A PHOTOCOLORIMETRIC METHOD OF DETERMINING ZIRCONIUM]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

210. Sheshulin, G.I., and A.I. Suderkin, Primeneniye metoda lyuminestsentsii dlya izucheniya kristallov opticheskogo kal'tsita. [THE USE OF THE LUMINESCENCE METHOD IN STUDYING CRYSTALS OF OPTICAL CALCITE]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

211. Shirokova, I.Ya., O protsessakh sul'fidno

mineralizatsii v rayone gory Sharabrinoy (Ural). [THE PROCESSES OF SULFIDE MINERALIZATION IN THE AREA OF MT. SHRABRINA (URALS)]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

2. Shcherbina, V.N., Nekotoryye osobennosti raspredeleniya sil'vina vo vkraplennykh sil'vinitovykh porodakh Pripyatskogo solyanogo basseyna. [SOME FEATURES OF THE DISTRIBUTION OF SYLVITE IN THE DISPERSED SYLVITE-CONTAINING ROCKS OF THE PRIPYAT SALINE BASIN]: Vestsi. Akad. Nauk BSSR, ser. fiz.-tekhn. navuk, no. 4, 1959.

3. Efendiyev, G.Kh., and A.S. Geydarov, K geokhimii molibdena v Dalidagskom intruzive (Malyy Kavkaz). [THE GEOCHEMISTRY OF MOLYBDENUM IN THE DALIDAG INTRUSIVE (LESSER CAUCASUS)]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

4. Yurevich, A.L., K petrograficheskoy kharakteristike akchagyl'skikh otlozheniy Pribalkhanskogo rayona. [THE PETROGRAPHIC CHARACTERISTICS OF THE AKCHAGYL DEPOSITS IN THE BALKHAN REGION]: Doklady, Akad. Nauk SSSR, t. 130, no. 4.

MINERAL RESOURCES AND METHODS OF LOCATION AND PROSPECTING

5. Abrakhams, A.P., Radioavtograficheskoye opredeleniye radioaktivnosti porod. [RADIOAUTOGRAPHIC DETERMINATION OF THE RADIOACTIVITY IN ROCKS]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

6. Antropov, P.Ya., Zadachi nauchno-issledovatel'skikh rabot po teoreticheskim osnovam poiskov i razvedki neftyanykh i gazovykh mestorozhdeniy v svete resheniy XXI s"yezda KPSS i iyun'skogo Plenuma TsK KPSS. [THE TASKS OF SCIENTIFIC RESEARCH ON THE THEORETICAL PRINCIPLES OF EXPLORATION AND PROSPECTING OF GAS AND OIL DEPOSITS IN THE LIGHT OF THE XXI CONGRESS OF THE COMMUNIST PARTY OF THE SOVIET UNION AND THE JUNE PLENUM OF THE CENTRAL COMMITTEE OF THE COMMUNIST PARTY OF THE SOVIET UNION]: Geol. nefti i gaza, no. 1.

7. Bagchi, T.S., Mestorozhdeniye izumrudov Bubani. [THE BUBAN' EMERALD DEPOSIT]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

218. Barsukov, V.L., and G.B. Naumov, Nekotoryye zamechaniya po povodu stat'i A.G. Betekhtina "O povedenii radioaktivnykh elementov pri protsessakh obrazovaniya endogennykh mestorozhdeniy". [SOME REMARKS ON A.G. BETEKHTIN'S ARTICLE, "ON THE BEHAVIOR OF RADIOACTIVE ELEMENTS IN THE FORMATION OF ENDOGENIC DEPOSITS"]: Geol. rudn. mestorozhd., no. 6, 1959.

219. Bachaldin, V.I., O zonal'nom raspredelenii mestorozhdeniy v Poladaurskom rudnom pole. [THE ZONAL DISTRIBUTION OF THE DEPOSITS IN THE POLADAUR ORE FIELD]: Geol. rudn. mestorozhd., no. 5, 1959.

220. Beneslavskiy, S.I., Znacheniye obogatimosti boksitov pri ikh otsenke. [THE IMPORTANCE OF THE BENEFICIATION PROSPECTS IN THE EVALUATION OF BAUXITES]: Byul. nauch.-tekhn. inform. M-va geol. i okhrani nedr SSSR, no. 7(24), 1959.

221. Berdichevskaya, M.Ye., and A.M. Leytes, Medenosnost' vostochnoy chasti. Udokanskogo khrebta. [THE COPPER CONTENT OF THE EASTERN PART OF THE UDOKAN RANGE]: Razv. i okhrana nedr., no. 1.

222. Betekhtin, A.G., O zamechaniyakh V.L. Barsukova i G.B. Naumova. [ON THE SUBJECT OF THE REMARKS BY V.L. BARSUKOV AND G.B. NAUMOV]: Geol. rudn. mestorozh., no. 6, 1959.

223. Betekhtin, A.G., Ob ekzogennykh protsessakh obrazovaniya uranovykh mestorozhdeniy. [ON THE EXOGENIC PROCESSES OF FORMATION OF URANIUM DEPOSITS]: Geol. rudn. mestorozhd., no. 6, 1959.

224. Bilibina, T.V., and Yu.V. Bogdanov, O perspektivakh zolotonosnosti v rayone Mugodzhar. [THE GOLD PROSPECTS OF THE MUGODZHAR REGION]: Geol. rudn. mestorozhd., no. 5, 1959.

225. Borodin, L.S., O perovskitovom orudenenii v massive vuoyarvi. [THE PEROVSKITE MINERALIZATION IN THE VUOYARVA MASSIF]: Geol. rudn. mestorozhd., no. 5, 1959.

226. Brodin, B.V., Mineral'nyy sostav i zakonomernosti rasprostraneniya orudeneniya Kurganskogo uzla (Talasskiy Alatau). [THE MINERAL COMPOSITION AND THE LAWS GOVERNING THE DISTRIBUTION OF THE MINERALIZATION IN THE KURGAN ORE NODE (TALASSKIY ALATAU)]: Geol. rudn. mestorozhd., no. 5, 1959.

227. Bushinskiy, G. I., Kriticheskiy obzor sovetskoy literatury po boksitam za 1955-1957 gg. [A CRITICAL REVIEW OF THE SOVIET LITERATURE ON BAUXITES FROM 1955 to 1957]: Byul. MOIP, otd. geol. t. 34, vyp. 4, 1959.

228. Bykhover, N. A., and A. F. Opalayev, Mineral'nosyr'yevaya baza kapitalisticheskikh stran. [THE MINERAL RAW MATERIAL RESERVES OF THE CAPITALIST COUNTRIES]: Razv. i okhrana nedr, no. 12, 1959.

229. Vasil'yev, V. G., I. Ye. Drabkin and V. A. Titov, Novyye dannyye kharakterizuyushchiye perspektivy neftegazonosnosti severo-vostochnykh rayonov SSSR. [NEW DATA ON THE OIL AND GAS PROSPECTS OF THE NORTHEASTERN AREAS OF THE USSR]: Novosti neft. tekhniki, geologiya, no. 12, 1959.

230. Velikaya, N. N., Vzaimootnosheniye daykovogo kompleksa porod s polimetallicheskim orudeneniyem v Kyzyl-Espinskom rudnom pole (Tsentral'nyy Kazakhstan). [THE INTERRELATIONSHIP BETWEEN THE COMPLEX OF DIKE ROCKS AND THE POLYMETALLIC ORE MINERALIZATION IN THE KYZYL-ESPA ORE FIELD (CENTRAL KAZAKHSTAN)]: Sov. geol., no. 12, 1959.

231. Vershinin, A. S., Osobennosti metodiki poiskov uranovykh mestorozhdeniy v zone glumidnogo klimata. [SOME SPECIAL FEATURES OF THE METHODS OF LOCATING URANIUM DEPOSITS IN HUMID CLIMATE ZONES]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 7(24), 1959.

232. Vladimirov, N. P., O vozmozhnosti ispol'zovaniya yestestvennogo elektromagnitnogo polya Zemli dlya geologicheskoy razvedki. [THE POSSIBILITIES OF USING THE EARTH'S NATURAL ELECTROMAGNETIC FIELD IN GEOLOGIC PROSPECTING]: Izv. Akad. Nauk SSSR, ser. geofiz. no. 1.

233. Vol'vovskiy, B. S., I. S. Vol'bobskiy and B. B. Tal'-Virskiy, Primeneniya seysmorazvedki dlya poiskov mestorozhdeniy nefti i gaza v Ferganskoy doline. [THE USE OF SEISMIC SURVEYS IN LOCATING OIL AND GAS DEPOSITS IN THE FERGANA VALLEY]: Geol. nefti i gaza, no. 1.

234. Golov, A. Ye., Syr'yevaya baza vengerskoy alyuminiyevoy promyshlennosti. [THE RAW MATERIAL RESOURCES OF THE HUNGARIAN ALUMINUM INDUSTRY]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

235. Grechishnikov, N. P., Nekotoryye zamechaniya o stat'ye V. I. Skoka "Ob otsenke tekhnologicheskikh svoystv koksuyushchikhsya ugley Kuznetskogo basseyna po kernovym probam". [SOME REMARKS ON V. I. SKOK'S ARTICLE, "ON EVALUATING THE TECHNOLOGICAL PROPERTIES OF THE COKING COALS OF THE KUZNETS BASIN BY MEANS OF CORE SAMPLES"]: Sov. geol., no. 12, 1959.

235. Danchev, V. I., et al. Ob uranovom orudenenii v karbonatnykh osadochnykh porodakh. [URANIUM MINERALIZATION IN CARBONATE SEDIMENTARY ROCKS]: Geol. rudn. mestorozhd., no. 6, 1959.

237. Dolgikh, S. A., Strukturnyye osobennosti berezovskogo mestorozhdeniya na Altaye. [THE STRUCTURAL PECULIARITIES OF THE BEREZOVKA DEPOSIT IN THE ALTAY]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 4(37), 1959.

238. Zhilo, P. V., O geograficheskom razmeshchenii osnovnykh bogatstv prirodnogo sul'fata natriya SSSR i znacheniye Kaspiyskogo sul'fatnogo rayona. [THE GEOGRAPHIC DISPOSITION OF THE MAIN NATURAL SODIUM SULFATE RESOURCES IN THE USSR AND THE SIGNIFICANCE OF THE CASPIAN SULFATE REGION]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

239. Zauer, L. M., K voprosu ob ispol'zovanii rasteniy-indikatorov v geologii. [THE PROBLEM OF THE USE OF PLANT-INDICATORS IN GEOLOGY]: Vestn. LGU, ser. geol. i geogr., no. 24, vyp. 4, 1959.

240. Zlizina, A. G., K voprosu klassifikatsii zalezhey nefta i gaza. [THE CLASSIFICATION OF OIL AND GAS DEPOSITS]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 3(36), 1959.

241. Zontov, N. S., Geologicheskaya struktura zhil'nogo medno-nikelevogo mestorozhdeniya Severnogo mysa gory Rudnoy (Noril'skiy rayon). [THE GEOLOGIC STRUCTURE OF THE COPPER-NICKEL VEIN DEPOSITS IN THE NORTHERN PROMONTORY OF MT. RUDNAYA (NORIL'SK REGION)]: Geol. rudn. mestorozhd., no. 5, 1959.

242. Ibragimov, Z. S., Fizicheskiye parametry neftegazonosnykh gorizontov melovykh i paleogenovykh otlozheniy Ferganskoy depressii. [THE PHYSICAL PARAMETERS OF THE OIL- AND GAS-CONTAINING STRATA IN THE CRETACEOUS AND PALEOGENE DEPOSITS OF THE FERGANA DEPRESSION]: Uzb. geol. zh., no. 6, 1959.

3. Ivanitskiy, T.V., Gidrotermal'nyy metamorfizm porod, vmeshchayushchikh svintsovo-tsinkovyye i polimetallicheskiye mestorozhdeniya Gruzii. [THE HYDROTHERMAL METAMORPHISM OF THE ROCKS CONTAINING THE LEAD-ZINC AND POLYMETALLIC DEPOSITS OF GEORGIA]: Geol. rudn. mestorozhd., no. 6, 1959.

4. Ivanov, A.A., and A.A. Makarenko, Shedokskoye mestorozhdeniye kamennoy solinovaya baza pishchevoy i khimicheskoy promyshlennosti. [THE SHEDOK DEPOSIT OF ROCK SALT—A NEW RESOURCE FOR THE FOOD AND CHEMICAL INDUSTRY]: Byul. nauch. -tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

5. Ivanov, M.V., Rol' mikroorganizmov v genezise i metamorfizatsii sernykh mestorozdeniy. [THE ROLE OF MICROORGANISMS IN THE GENESIS AND METAMORPHISM OF SULFUR DEPOSITS]: Zh. obshch. biol., t. 21, no. 1.

6. Kalinko, M.K., O perspektivakh neftegazonosnosti Khatangskoy vpadiny. [THE OIL AND GAS PROSPECTS OF THE KHATANGA BASIN]: Novosti neft. tekhniki, geologiya, no. 12, 1959.

7. Kashkay, M.A., Alunitizatsiya, pirofillitizatsiya i kaolinizatsiya vulkanogennykh porod i klassifikatsia alunitovykh mestorozhdeniy. [ALUNITIZATION, PYROPHYLLITIZATION AND KAOLINIZATION OF VOLCANOGENIC ROCKS AND THE CLASSIFICATION OF ALUNITE DEPOSITS]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

8. Kozlova, V.D., Iz olyta razvedki zhelezorudnykh mestorozhdeniy Yuzhnoy Yakutii. [THE EXPERIENCE OF PROSPECTING THE IRON-ORE DEPOSITS OF SOUTHERN YAKUTIYA]: Byul. nauchn. -tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

49. Konstantinov, G.M., O novom tipe olovyannykh rud v dolomitakh Malogo Khingana. [A NEW TYPE OF TIN ORE IN THE DOLOMITES OF THE LESSER KHINGAN]: Geol. rudn. mestorozhd., no. 6, 1959.

50. Korolev, A.V., and S.T. Badalov, O pervichnoy zonal'nosti orudeneniya v Almalykskom rudnom pole. [THE PRIMARY ZONALITY IN THE MINERALIZATION OF THE ALMALYK ORE FIELD]: Geol. rudn. mestorozhd., no. 5, 1959.

51. Kreyter, V.M., and V.I. Biryukov, Po povodu broshyury K.I. Krolivetskogo "O printsipakh razvedki poleznykh izkopayemykh". [ON THE SUBJECT OF K.I. KROLIVETSKIY'S PAMPHLET, "THE PRINCIPLES OF PROSPECTING FOR ECONOMIC MINERALS"]: Razv. i okhrana nedr, no. 1.

252. Krems, A.Ya., Perspektivy prirosta promyshlennyich zapasov nefti i gaza v Timano-Pechorskoy provintsii v 1959-1965 gg. [THE PROSPECTS FOR AUGMENTING THE INDUSTRIAL RESERVES OF OIL AND GAS IN THE TIMAN-PECHORA PROVINCE FROM 1959 to 1965]: Geol. nefti i gaza, no. 1.

253. Kudryavtsev, N., O knige A.L. Kozlova "O zakonomernostyakh formirovaniya i razmeshcheniya neftyanykh i gazovykh zalezhey". [ON A.L. KOZLOV'S BOOK, "THE LAWS GOVERNING THE FORMATION AND DISTRIBUTION OF OIL AND GAS DEPOSITS"]: Geol. nefti i gaza, no. 1.

254. Lovell, D.D., Uran v diatreme Set-lakey, Khopi B'yutts, Arizona. [URANIUM IN THE SET-LA-KAY DIATREME, HOPI BUTTES, ARIZONA]: Byul. nauchn. -tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

255. Lukashev, K.I., and N.N. Petukhova, O mikroelementakh vёssovykh porodakh territorii Belorussii. [THE MINOR ELEMENTS IN THE LOESSIAL ROCKS OF BELORUSSIA]: Doklady, Akad. Nauk BSSR, t. 3, no. 12, 1959.

256. Opredeleniye mestopolozheniya radioaktivnykh proyavleniy. [DETERMINATION OF THE LOCATION OF RADIOACTIVE PHENOMENA]: Byul. nauchn. -tekn. inform. M-va geol. i okhrany nedr SSSR, no. 6(23), 1959.

257. Ostryy, B.S., O metodike poiskov strukturnykh podnyatiy na severo-vostoke Zapadno-Sibirskoy nizmennosti. [ON THE METHODS OF LOCATING STRUCTURAL UPLIFTS IN THE NORTHEASTERN PART OF THE WESTERN SIBERIAN LOWLAND]: Novosti neft. tekhniki, geologiya, no. 12, 1959.

258. Pelymskiy, G.A., Ovliyanii vmeshchayushchikh porod na protsessy rudootlozheniya v gidrotermal'nykh urana. [THE INFLUENCE OF THE HOST ROCKS ON THE PROCESS OF ORE DEPOSITION IN HYDROTHERMAL URANIUM DEPOSITS]: Geol. rudn. mestorozhd., no. 6, 1959.

259. Pigulevskiy, N.A., et al. Osobennosti polimetallicheskogo orudeneniya Dzhungarskogo Alatay i dal'neysheye

napravleniye poiskovo-razvedochnykh rabot. [SPECIAL FEATURES OF THE POLYMETALLIC MINERALIZATION OF THE DZHUNGARSKIY ALATAU AND FUTURE TRENDS IN PROSPECTING AND LOCATION OPERATIONS]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 4(37), 1959.

260. Polevoy, V.S., Poiski i razvedka zakarstovannykh zon geofizicheskimi metodami. [GEOPHYSICAL METHODS OF LOCATING AND PROSPECTING KARSTIFIED ZONES]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

261. Polikarpochkin, V.V., and V.A. Lapp, Oreoly rasseyaniya zolota v ilistoglinistoy fraktsii allyuvial'nykh otlozheny i ispol'zovaniye ikh pri poiskakh. [GOLD DISPERSION HALOS IN THE CLAY-OOZE FRACTION OF ALLUVIAL DEPOSITS AND THEIR USE IN PROSPECTING]: Byul. nauchn.-tekhn. inform. M-va geol. i okhrany nedr. SSSR, no. 6(23), 1959.

262. Prokin, V.A., O plotnosti razvedochnoy seti na kolchedannykh mestorozhdeniyakh Urala. [THE DENSITY OF THE SURVEY NET IN THE PYRITIC DEPOSITS OF THE URALS]: Byul. nauchn.-tekhn. inform. M-va geol. i okhrany nedr. SSSR, no. 6 (23), 1959.

263. Raaben, V.F., Formirovaniye zalezhey nefti v nizhnekamennougol'nykh otlozheniyakh Kamsko-Kinel'skoy vpadiny. [THE FORMATION OF OIL OCCURRENCES IN THE LOWER CARBONIFEROUS DEPOSITS OF THE KAMA-KINEL' BASIN]: Novosti neft. tekhniki, geologiya, no. 12, 1959.

264. Ratner, V.Ya., O tipakh zalezhey nefti i gaza na Severnom Sakhaline. [THE TYPES OF OIL AND GAS OCCURRENCES IN NORTHERN SAKHALIN]: Novosti neft. tekhniki, geologiya, no. 12, 1959.

265. Rozov, B.S., Ekonomika sur'myanoy promyshlennosti kapitalisticheskikh stran. [THE ECONOMICS OF THE MERCURY INDUSTRY IN THE CAPITALIST COUNTRIES]: Byul. nauchn.-tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6 (23), 1959.

266. Romanovich, I.F., O roli erozionnogo sreza giperbazitovykh intruzivov i glubinnosti metasomaticheskikh protessov v otsenke tal'konosnosti. [THE ROLE OF THE EROSIONAL TRUNCATION OF HYPERBASITE INTRUSIVES AND THE DEPTH OF METASOMATIC PROCESSES IN THE ESTIMATION OF TALC CONTENT]: Byul. MOIP, otd. geol. t. 34, vyp. 4, 1959.

267. Sazhina, N.B., Detal'naya gravimetricheskaya s"yemka pri poiskakh neftegazonosnykh struktur. [DETAILED GRAVIMETRIC SURVEYING IN LOCATING GAS AND OIL-BEARING STRUCTURES]: Byul. nauch.-tekhn. inform. M-va geol. i okhrany nedr, SSSR, no. 6(23), 1959.

268. Saranchina, G.M., and N.V. Kotov, K izucheniyu rayona Dzhilauskogo mestorozhdeniya (Tadzhikistan). [THE STUDY OF THE AREA OF THE DZHILAU DEPOSIT (TADZHIKISTAN)]: Vestn. LGU, no. 24, ser. geol. i geogr. vyp. 4, 1959.

269. Satybaldin, K.Sh., Svyaz'redkometal'nykh shtokverkov Uspensko-Shegskogo rayona s regional'nymi strukturami Tsentral'nogo Kazakhstana. [THE CONNECTION BETWEEN THE RARE-METAL STOCKWORK DEPOSITS OF THE USPENSK SHEG DISTRICT AND THE REGIONAL STRUCTURES OF CENTRAL KAZAKHSTAN]: Izv. Akad. Nauk KazSSR, ser. geol. vyp. 3(36), 1959.

270. Sen'ko, A.K., P.P. Klevtsov, V.B. Sal'tsevich, and P.P. Khitev, Fotoneytronnyy metod karotazha na berilliy. [A PHOTONEUTRON METHOD OF LOGGING FOR BERYLLIUM]: Byul. nauchn.-tekhn. inform. M-va geol. i okhrany nedr. SSSR, no. 6(23), 1959.

271. Smirnov, V.I., K voprosu o klassifikatsii rudno-petrograficheskikh provintsiy. [ON THE CLASSIFICATION OF ORE-PETROGRAPHIC PROVINCES]: Uzb. geol. zh., no. 6, 1959.

272. Stepanov, V.V., Posledovatel'nost formirovaniya redkometal'nogo shtokverka Saran. [THE SUCCESSION IN THE FORMATION OF THE SARAN RARE-METAL STOCKWORK]: Izv. Akad. Nauk KazSSR, ser. geol. vyp. 3(86), 1959.

273. Sudarikov, Yu.A., Paleogenovaya istoriya razvitiya i otsenka perspektiv gazoneftenosnosti Iki-Burul'skogo podnyatiya. [THE PALEOGENE HISTORY AND AN EVALUATION OF THE OIL AND GAS PROSPECTS OF THE IKI-BURUL' UPLIFT]: Izv. vyssh uchebn. zaved., ser. neft' i gaz, no. 1.

274. Surazhskiy, D.Ya., Morfologicheskiye tipy promyshlennykh mestorozhdeniy urana i metody ikh razvedki. [THE MORPHOLOGICAL TYPES OF INDUSTRIAL URANIUM DEPOSITS AND THE METHODS OF PROSPECTING THEM]: Atomnaya energiay, t. 7, vyp. 6, 1959.

275. Sukhanova, Ye.N., Sluchay obrazovaniy koksa v uglyakh pod vozdeystviyem sul'fidnoy zhily. [A CASE OF COKE FORMATION IN COALS UNDER THE INFLUENCE OF A SULFIDE VEIN]: Geol. rudn. mestorozhd., no. 6, 1959.

6. Tabyldiyev, K.T., Strukturnyye osobennosti fosforitovogo mestorozhdeniya Chulaktau. [SOME STRUCTURAL FEATURES OF THE CHULAKTAU PHOSPHORITE DEPOSIT]: Izv. Akad. Nauk KazSSR, ser. geol. vyp. 3(36), 1959.

7. Tugovik, G.I., O sostave i proiskhozhdenii trubchatogo tela Buluktayevskogo molibdeno-vol'framovogo mestorzhdeniya (Zapadnoye Zabaykal'ye). [ON THE COMPOSITION AND ORIGIN OF THE PIPE-SHAPED ORE BODY OF THE BULUKTAYEV MOLYBDENUM-WOLFRAM DEPOSIT (WESTERN TRANSBAYKAL)]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 11, 1959.

8. Favorskaya, M.A., Otnosheniye redkometal'nogo i polimetallicheskogo orudeneniya k intruzivnym i effuzivnym formatsiyam v nekotorykh rayonakh Tikhookeanskogo poyasa. [THE RELATIONSHIP OF RARE-METAL AND POLYMETALLIC MINERALIZATION TO THE INTRUSIVE AND EXTRUSIVE FORMATIONS IN SOME AREAS OF THE CIRCUMPACIFIC BELT]: Sov. geol., no. 12, 1959.

9. Khanin, A.A., Kollektory nefti sredne- i nizhnepaleogenovykh otlozheniy Akhtyrsko-Burundyrskogo mestorozhdeniya. [OIL RESERVOIRS IN THE LOWER AND MIDDLE PALEOZOIC SEDIMENTS OF THE AKHTYR-BUGUNDYR DEPOSIT]: Geol. nefti i gaza, no. 1.

30. Khanin, A.A., Opredeleniye koeffitsiyentov gaza i neftenasyshchennosti gornykh porod. [DETERMINATION OF THE GAS-AND OIL-SATURATION COEFFICIENTS IN ROCKS]: Razv. i okhrana nedr, no. 1.

31. Khushchov, N.A., Klassifikatsiya mestorozhdeniy molibdena. [THE CLASSIFICATION OF MOLYBDENUM DEPOSITS]: Geol. rudn. mestorozhd., no. 6, 19591

32. Churikov, V.A., K voprosy o proiskhozhdenii zhil'nogo prostranstva na primere Severo-Kounradskogo vol'famovorudnogo mestorozhdeniya. [ON THE ORIGIN OF VEIN SPACE, FROM THE EXAMPLE OF THE NORTHERN KOUNRAD WOLFRAM-ORE DEPOSIT]: Sov. geol. no. 12, 1959.

33. Shadlun, T.N., Nekotoryye zakonomernosti proyavleniya metamorfizma v bogatykh piritom svintsovo-tsinkovykh rudakh Tekeliyskogo mestorozhdeniya. [SOME LAWS GOVERNING THE OCCURRENCE OF METAMORPHISM IN THE PYRITE-RICH LEAD-ZINC ORES OF THE TEKELIY DEPOSIT]: Geol. rudn. mestorozhd., no. 5, 1959.

284. Shcheglov, A.D., K voprosy o genezise vol'framovykh mestorozhdeniy Zabaykal'ya. [ON THE GENESIS OF THE WOLFRAM DEPOSITS OF THE TRANSBAYKAL]: Geol. rudn. mestorozhd., no. 6, 1959.

285. Yakoulev, G.F., and V.N. Vydrin, Geologo-structurnyye zakonomernosti razmeshcheniya polimetallicheskikh mestorozhdeniy v Zmeinogoroskom rayone (Rudnyy Altay). [GEOLOGIC STRUCTURAL LAWS GOVERNING THE EMPLACEMENT OF THE POLYMETALLIC DEPOSITS IN THE ZMEINOGORSK REGION (RUDNYY ALTAY)]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

286. Yakubov, A.A., Gryazevyye vulkany Azerbaydzhana, ikh genezis i svge' s razoneftyanymi mestorozhdeniyami. [THE MUD VOLCANOES OF AZERBAYDZHAN, THEIR GENESIS AND THEIR ASSOCIATION WITH GAS AND OIL DEPOSITS]: Sov. geol., no. 12, 1959.

287. Yakubov, A.A., and F.M. Bagirzade, Monografiya omestorozhdenii Neftyanyye Kamni (O knige F.I. Samedova). [THE MONOGRAPHS ON THE NEFTYANYYE KAMNI DEPOSIT (ON THE BOOK BY F.I. SAMEDOV)]: Izv. vyssh. uchebn. zaved., ser. nefti i gaz, no. 1.

288. Yaroshenko, F.D., Mineral'nyye resursy Indii. [THE MINERAL RESOURCES OF INDIA]: Byul. nauchn.-tekhn. inform. M-va geol. i okhrany nedr, SSSR, no. 7 (24), 1959.

HYDROGEOLOGY, ENGINEERING GEOLOGY

289. Akhmedsafin, U.M., Karta prognoza artezianskikh basseynov Kazakhstana [A PROGNOSTIC MAP OF THE ARTESIAN BASINS OF KAZAKHSTAN]: Vestn. Akad. Nauk KazSSR, no. 11, 1959.

290. Akhundov, A.R., and Ya.M. Bashirov, Kharakteristika vod KS i PK svity mestorozhdeniya Banka Darvina. [THE PROPERTIES OF THE WATERS IN THE KS AND PK SUITES OF THE BANK DARVIN DEPOSIT]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 12, 1959.

291. Bekturova, A.B., A.I. Mun and M.I. Bakeyev, Gidrokhimicheskiy rezhim ozera Zhalauly i vozmozhnyye puti ego osvoyeniya. [THE HYDROGEOCHEMICAL REGIME OF LAKE ZHALAULY AND POSSIBLE MEASURES FOR ITS EXPLOITATION]: Vestn. Akad. Nauk. KazSSR, no. 12, 1959.

292. Bondarenko, S.S., Yodno-bromnyye vody Povolzh'ya i Prikam'ya. [THE IODINE-BROMINE WATERS OF THE VOLGA AND KAMA RIVER REGIONS]: Sov. geol., no. 12, 1959.

293. Bondarenko, S.S., Osnovnyye cherty gidrogeologii Volgo-Ural'skogo artezianskogo basseyna. [MAIN FEATURES OF THE HYDROGEOLOGY OF THE VOLGA-URALS ARTESIAN BASIN]: Izv. vyssh. uchebn. zaved. ser. geol. i razvedka, no. 11, 1959.

294. Budanov, N.D., Opyt regional'noy otsenki resursov podzemnykh vod na Urale. [AN EXPERIMENT IN THE REGIONAL EVALUATION OF THE GROUND WATERS IN THE URALS]: Razv. i okhrana nedr, no. 12, 1959.

295. Vartanyan, G.S., Gidrogeologicheskiye usloviya mestorozhdeniya Neftyanyye Kamni (Apsheron). [THE HYDROGEOLOGIC CONDITIONS IN THE NEFTYANYYE KAMNI DEPOSIT (APSHERON)]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

296. Viktorov, S.V., and Ye.A. Vostokova, Znacheniye geobotanicheskikh nablyudeniy dlya rabot gidrogeologicheskikh i opolznevykh stantsiy. [THE IMPORTANCE OF GEOBOTANICAL OBSERVATIONS FOR THE WORK OF HYDROGEOLOGICAL AND LANDSLIDE OBSERVATION STATIONS]: Byul. nauchn.-tekhn. inform. M-va geol. i okhrany nedr, SSSR, no. 7(24), 1959.

297. Dal'yan, I.B., and Zh. Sydykov, Novyye dannyye o podzemnykh vodakh neokoma Severnoy Emby. [NEW DATA ON THE GROUND WATERS OF THE NEOCOMIAN DEPOSITS IN THE NORTHERN EMBA REGION]: Izv. Akad. Nauk KazSSR, ser. geol. vyp. 4(37), 1959.

298. Dubrovkin, V.I., and Ye.G. Chapovskiy, Voprosy metodiki sostauleniya inzhenerno geologicheskikh kart. [SOME METHODOLOGICAL PROBLEMS OF PREPARING ENGINEERING GEOLOGIC MAPS]: Izv. vyssh. uchebn. zaved., ser. geol., i razvedka, no. 10, 1959.

299. Yemel'yanova, Ye.P., O znachenii litologicheskogo sostava gornykh porod v opolznevykh protsessakh i klassifikatsii opolzney. [ON THE SIGNIFICANCE OF THE LITHOLOGIC COMPOSITION OF ROCKS IN LAND SLIDE PROCESSES AND IN THE CLASSIFICATION OF SLIDES]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 10, 1959.

300. Zerchaninov, I.K., K voprosam gidrogeologii Saratovskogo i Stalingradskogo Povolzh'ya. [PROBLEMS OF HYDROGEOLOGY IN THE SARATOV AND STALINGRAD AREAS OF THE VOLGA REGION]: Geol. nefti i gaza, no. 1.

301. Israfilov, G.Yu., Opyt rayonirovaniya Kura-Araksinskoy nizmennosti po tipam rezhima urovnya gruntovykh vod. [AN EXPERIMENT IN THE REGIONALIZATION OF THE KURA-ARAKS LOWLAND ACCORDING TO THE TYPES OF GROUN WATER LEVEL REGIMES]: Byul. nauch tekhn. inform. M-va geol. i okhrany nedr SSSR, no. 6(38), 1959.

302. Korotkevich, G.V., Karst severoural'skogo mestorozhdeniya boksitov Krasnaya Shapochka i voprosy glubinnogo karstoobrazovaniya. [THE KARST OF THE KRASNAYA SHAPOCHKA DEPOSITS OF BAUXITES IN THE NORTHERN URALS AND THE PROBLEMS OF DEEP KARST FORMATION]: Vestn. LGU, no. 24, ser. geol. i geogr., vyp. 4, 1959.

303. Lomize, G.M., Zakonomernosti malykh plasticheskikh deformatsiy v oblasti uprochneniya dispersnogo grunta. [THE LAWS GOVERNING SMALL PLASTIC DEFORMATIONS IN THE ZONE OF HARDENING OF A DISPERSED SOIL]: Doklady Akad. Nauk, SSSR, t. 130, no. 1.

304. Mavritskiy, B.F., Zakonomernosti rasprostraneniya gruntovykh vod Irtyshskoy vpadiny. [THE LAWS GOVERNING THE DISTRIBUTION OF SOIL WATERS IN THE IRTYSH BASIN]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

305. Magerramova, F.S., Vody apsheronskog yarosa neftyanykh mestorozhdeniy tsentral'noy chasti Apsheronskogo poluostrov [THE WATERS OF THE APSHERON STA IN THE OIL DEPOSITS OF THE CENTRA PART OF THE APSHERON PENINSULA]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 11, 1959.

306. Molokov, L.A., Izucheniye zapolnitelya karstovykh polostey i ego fil'tratsionnoy ustoychivosti. [A STUDY OF THE MATERIAL FILLING KARST CAVITIES AND OF ITS FILTRATIONAL STABILITY Byul. MOIP, otd. geol. t. 34, vyp. 4, 1959.

307. Mukhamedzhanov, S.M., O kompleksnykh inzhenerno-geologicheskikh issledovaniya na trasse kanala Irtysh-Karaganda. [COM PLEX ENGINEERING GEOLOGIC INVESTIGATIONS ALONG THE TRASS OF THE IRTYSH-KARAGANDA CANAL]: Vestn. Akad. Nauk KazSSR, no. 12, 1959.

8. Mukhin, Yu. V., Nekotoryye dannyye o podzemnykh vodakh Ryazano-Kostromskogo progiba. [SOME DATA ON THE GROUND WATERS OF THE RYAZAN-KOSTROMA DEPRESSION]: Byul. MOIP, otd. geol., t. 34, vyp. 4, 1959.

9. Perel'man, A. I., Epigeneticheskiye izmeneniya v osadochnykh porodakh i ziacheniye ikh izucheniya dlya paleogidrogeologii. [EPIGENETIC ALTERATIONS OF SEDIMENTARY ROCKS AND THEIR SIGNIFICANCE IN THE STUDY OF PALEOHYDROGEOLOGY]: Byul. MOIP, otd. geol. t. 34, vyp. 4, 1959.

10. Professor I. V. Popov. Yubiley. [PROFESSOR I. V. POPOV: JUBILEE ANNIVERSARY]: Izv. vyssh. uchebn. zaved. ser. geol. i razvedka, no. 10, 1959.

11. Posokhov, Ye. V., O stat'ye, B. A. Bedera vody artezianskikh basseynov Uzbekistana (Uzb. geol. zh., 1958, no. 6). [CONCERNING B. A. BEDER'S ARTICLE, "THE WATERS OF THE ARTESIAN BASINS OF UZBEKISTAN"]: Uzb. geol., zh., no. 6, 1959.

12. Smirnov, B. N., Gidrogeologicheskiye usloviya Yakovlevskogo zhelezorudnogo mestorozhdeniya. [THE HYDROGEOLOGIC CONDITIONS IN THE YAKOVLEV IRON-ORE DEPOSIT]: Razv. i okhrana nedr, no. 12, 1959.

13. Shirinov, N. Sh., Morfologiya i nekotoryye voprosy dinamiki sovremennykh beregov Apsheronskogo poluostrova. [THE MORPHOLOGY AND SOME PROBLEMS OF THE DYNAMICS OF THE PRESENT SHORES OF THE APSHERON PENINSULA]: Izv. Akad. Nauk AzerbSSR, ser. geol.-geogr. nauk, no. 6, 1959.

B. Articles in "Materialy", "Trudy", "Uchenyye Zapiski" and "Sborniki"

1. Vikoristannya Prirodnikh Likuval'nikh Resursiv Ukraini. [Exploitation of the Natural Medicinal-Water Resources of the Ukraine]: Kiiv, 1959, 231 pp. Partial contents: Ovchinnikov, O. M., Laws governing the distribution of mineral-water resources in mountain structures of the USSR and adjoining countries. Babinets', A. E., Laws governing the distribution of mineral waters in the Ukrainian SSR and their comparison with the waters of other regions of the Soviet Union. Guk, V. V., et al., Balneological study of the mineral waters of the Ukraine and the prospects for their exploitation for medicinal purposes. Gayun, K. G., G. O. Goleva and D. I. Sklyaruk, The results of hydrogeological prospecting operations and a study of the mineral waters in the health resorts of the western parts of the Ukraine. Kudrin, L. M. and G. P. Alf'orov, The mineral waters of the Upper Tiss River basin in Transcarpathia. Goleva, G. O., The mineral waters of Northern Bukovina. Tsapenko, I. I., Hydrogen-sulfide springs in Podolia. Burkser, V. V. and B. B. Zaydis, The mineral waters of the city of Khmil'nik in the Vinnitsa oblast'. Gorban', O. K., New data on the hydrogeological operations in the area of the city of Khmil'nik in the Vinnitsa oblast'. Al'bov, S. V., The mineral waters of the Crimea and the principal means of exploiting them. Solyakov, I. P., The chemical composition of the ground waters of the Donets Basin and the possibility of utilizing certain types of them as mineral waters. Gayun, K. G. and M. O. Volkova, The hydrogeologic conditions in the littoral zone of western part of the Black Sea depression. Dzens-Litovskiy, O. I., The problem of providing a water supply and removing waste waters from the balneological resorts of the Crimea. Larionova, L. I., The hydrochemical characteristics of Lake Belikii Moynak. Sklyaruk, D. I., The mud lakes and limans of the Ukrainian SSR and their practical exploitation. Goncharov, P. I., N. A. Bilik and Ye. Yu. Kitaer, A study of the minor elements and organic remains in the medicinal muds of the Kuyal'nik liman.

2. Voprosy Gidrogeologii i Inzhenernoy Geologii. [Problems of Hydrogeology and Engineering Geology]: Sb. 18, Moscow, 1959, 184 pp. Partial contents: Ogil'vi, N. A., Some problems of the theory of hydrogeochemical fields. Al'tovskiy, M. Ye., The classification of ground waters. Shevchenko, N. G., The fresh waters of sand deserts (from the example of the Western Karakumy). Lebedev, A. V., Some results of a study of the moisture balance and dynamics in the aeration zone at the Moscow Hydrogeological Station. Churinov, M. V. and I. M. Tsypina, On the role of the most recent tectonic movements in the development of rock slide processes on the southern shore of the Crimea. Makkaveyev, A. A., The Quaternary deposits of the Pripyat Poles'ye (forest belt). Dukhanina, V. I., The stratigraphy of the Quaternary deposits of Lithuania. Ryabchenkov, A. S., Traces of permafrost in the glacial period in the basin of the Upper Don River. Skvortsov, G. G. and S. P. Prokhorov, The requirements for the engineering geologic study of economic mineral deposits.

3. Voprosy Istorii Yestestvoznaniya i Tekhniki.

[Problems of the History of Science and Technology]: Vyp. 7, Moscow, 1959, 198 pp. Partial contents: Konchev, S.K., On the history of the Kursk magnetic anomaly. Solov'yev, Yu. I., An unpublished letter from J. Bercelius to K. Klaus. Dotsenko, S.B., Geologic investigations in the Main Caucasus Range by Academician G.V. Abikh. Tolstoy, M.P., Concerning N.A. Golovkinskiy's veiws on the Earth's development.

4. Geologiya i Neftegazonosnost' Yuga SSSR. [Geology and Oil and Gas Content of the Southern USSR]: Vyp. 4, Dagestan, Leningrad, 1959, 431 pp. Partial contents: Kuprin, P.N., A review of the location and prospecting operations and the investigations of oil and gas in Dagestan. Nesmeyanov, D.V., The structural history and the oil and gas content of the marginal anticlinal zones of Dagestan. Seregin, A.M., The oil and gas contents of the Mesozoic deposits of Northern Dagestan, the Tera Sunzha and the Kuma regions.

5. Za Tekhnicheskiy Progress v Geologorazvedochnykh i Topografo-Geodezicheskikh Rabotakh. [For Technological Advancement in Geological Exploration and Topographic-Geodesic Operations]: Moscow, 1959, 252 pp. Partial contents: Zuyev, G.N., Methods of identifying ore bodies in the long-term surveying of polymetallic and rare-metal deposits. Smelov, A.A., On the necessity of studying the residual magnetization of rocks. Samarin, B.P., On improving the location of polymetallic deposits by geophysical methods. Erenburg, I.I., The use of X-ray analysis in the practical geological investigations of the Western Siberian Geological Administration. Rusanov, A.K., Spectrographic analysis of metallometric ore and mineral samples.

6. Kristallografiya [Crystallography]: T. 4, vyp. 6, Moscow, 1959, pp. 805-956. Partial contents: Kolontsova, Ye.V. and L.A. Ignat'yeva, Diffusional dispersion of X-rays by quartz crystals before and after neutron bombardment. Rumanova, I.M. and T.V. Nikolayeva, The crystal structure of orthite Vinokurov, V.M. and M.M. Zaripov, The magnetic properties of tourmaline. Pyatenko, Yu.A. and Z.V. Pudovkina, On the crystal structure of narsarsukite.

7. Materialy k Osvoyeniyu Golodnoy Stepi. [Materials on the Exploitation of the Golodnaya Steppe]: Tashkent, 1959, 187 pp. Partial contents: Krylov, M.M., The tasks of hydrogeological investigations associated with the exploitation of the Golodnaya Steppe. Beder, B.A., M.M. Ivanitsyn and Kh.T. Tulyaganov, The deep ground waters of the Taskhant artesian basin as a possible source of water supply for the crop lands of the Golodnaya Steppe. Khasanov, A.S., The sulfate and magnesium aggressiveness of the ground water of the Golodnaya Steppe. Opryshko, K. Ya., Some peculiarities of the hydrogeological conditions in the Shuruzyak depression in the northeastern part of the Golodnaya Steppe. Kenesarin, N.A., The influence of irrigational factors on the formation of the ground water regime in the Golodnaya Steppe. Kenesarin, N.A., The accumulation of salts in irrigated areas, the relationship between the form of salinification of the soil and the ground water regime, and measures used against irrigational salinification. Rulenko, V.V., The effect of natural and man-made factors on the ground water regime of the Golodnaya Steppe. Ganiyev, K.G., The ground water balance in Zone I and the Maintenance and Repair Station of the Syr-Dar'ya rayon. Mavlyanov, G.A., The shingles, gravels and sands of the Golodnaya Steppe.

8. Poleznyye Iskopayemyye Chitinskoy Oblasti. [Economic Minerals of the Chita Oblast']: Moscow, 1959, 141 pp. Contents: Arsen'yev, A.A. and A.M. Leytes, The geologic study and the geologic structure of the Chita Oblast'. Askasinskiy, V.V., Deposits of iron and manganese. Donenko, V.P., Fluorite deposits. Leytes, A.M., Piezooptical raw materials. Chernykh, A.S., Non-ore metallurgical raw materials. Rozanov, Yu.A., and V.A. Bol'shakov, Construction materials. Karpov, N.F., V.I. Konivets and L.I. Kuts, Coal deposits. Vasil'yev, V.G., V.S. Volkhonin, K.B. Mokshantsev and S.G. Sarkisyan, Oil prospects. Gurevich, M.G. and I.M. Ovchinnikov, Natural gas. L.M. Orlova, Mineral Springs.

9. Problemy Severa. [Problems of the Northern Regions]: Vyp. 3, Moscow, 1959, 206 pp. Partial contents: Armand, A.D., The transportation and deposition of alluvium in the channels of the mountain streams of the Vilyuy basin and their importance in the location of placer deposits of economic minerals. Vityurin, B.I., On the origin of the underground ice in the vicinity of the settlement of Anadyr'.

10. Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Zolota i Redkikh Metallov. Geologiya, vyp. 50. [Publications of the All-Union Scientific Research Institute of Gold and Rare Metals. Geology, No. 50]: Magadan, 1959, 36 pp. Contents: Nayborodin, V.I., The mineralogy and genesis of the ores of the Agylka deposit.

Shilo, N.A. and I.P. Kartashov, Placer deposits of gold in the Northeastern USSR.

Trudy Donetskogo Industrial'nogo Instituta. [Publications of the Donets Industrial Institute]: T. 37, ser. geol., vyp. 2, Stalino, 1959, 158 pp. Partial contents: Nikol'skiy, I.L., Concerning the so-called interformational slip joints. Levenshteyn, M.L., On the problem of the synonymy of the limestones and coal seams of the Lower Carboniferous in the southwestern part of the Donets Basin. Vasilyuk, N.P., The Chaetetids of the Upper Coal Measures deposits of the Donets Basin. Manukalova-Grebenyuk, M.F. and L.P. Nesterenko, The microfauna and some special features of the limestone reference stratum of the S_3 "folded" saliniferous series of the Lower Permian in the Donets Basin. Kulikovskiy, V.K., On the manifestations of igneous activity in the southwestern part of the Donets Basin. Buturlinov, N.V. and V.K. Kulikovskiy, A brief petrographic description of the igneous rocks in the southwestern areas of the Donets Basin. Buturlinov, N.V., Shonkinite from the southwestern part of the Donets Basin. Novichkova, N.I., The mineralogical composition of the sands of Middle Sarmatian age. Garkalenko, I.A., On the densities of the rocks in the western part of the Donets Basin. Panov, B.S., New data on the presence of mercury in the igneous rocks of the southwestern part of the Donets Basin. Ustinovich, N.S., The Petropavlovsk deposit of Lower Jurassic montmorillonite clays.

Trudy Instituta Geografii Akad. Nauk SSSR, t. 77, Materialy po Geomorf. i Paleogeogr. SSSR, vyp. 21. [Publications of the Institute of Geography of the USSR Vol. 77, Materials on the Geomorphology and Paleogeography of the USSR, No. 21]: Moscow, 1959, 199 pp. Partial contents: Grichuk, V.P., The lower boundary of the Quaternary period (system) and its stratigraphic position on the Russian Plain. Gubonina, Z.P., Preliminary data on a study of the Pleistocene deposits in the north of Western Siberia.

Trudy Instituta Geologii i Poleznykh Iskopayemykh Akad. Nauk LatvSSR. [Publications of the Institute of Geology and Economic Minerals of the Latvian SSR]: T. 4, Riga, 1959, 124 pp. Partial contents: Danilans, I.Ya., On the terminology and classification of post-glacial fresh-water limestones and their deposits. Danilans, I.Ya., The conditions of Holocene freshwater carbonate formation within the territory of Latvia. Bartosh, T.D., The stratigraphic association and the paleogeographic conditions of accumulation of Holocene lime deposits. Abolkalns, Yu. Ya., The conditions and the process of formation of the carbonates in the large deposits of Latvia.

14. Trudy Kazakhskogo Nauchno-Issledovatel'skogo Instituta Mineral'nogo Syr'ya. [Publications of the Kazakh Scientific Research Institute of Mineral Raw Materials]: Vyp. 1, Alma-Ata, 1959, 234 pp. Partial contents: Kobzar', P.N. and N.M. Belyashov, Some geochemical problems of the processes of formation of magnetite ores in contact-metasomatic deposits. Krol', O.F., An example of greisenization of alaskite granites. Yerdzhanov, K.N., Manifestations of greisenization in the Maytass granitic massif. Belyashov, N.M., The problem of the age of the Ayat iron-ore stratum in the Turgay Basin. Bryushkov, V.I., The age and the geology of the coal measures in the Upper Sokur district of the Karaganda Basin. Semenova, T.P., The absolute age of the intrusive rocks in the area of the Kendyktass Mountains of Kazakhstan, based on potassium-argon data. Yefimov, I.A. and I.I. Satrapinskaya, The methods of determining the contents by weight of accessory minerals in granitoids. Khalturina, I.I., On the minerals of the kyanite group in the mica schists of the Irtysh River region. Yefimov, I.A. and O.M. Rozen, Rutile in the eclogites of the Kokchetav anticlinorium. Koshelev, I.P., O.V. Shishakin, A.Kh. Mukhamedgaliyev and L.I. Shlyunin, The application of the photo-neutron method of well logging (neutron gamma-radiation logging) in the location and prospecting of beryllium. Toporkov, D.D., A.A. Borobeychik and L.P. Shadrin, Sampling and chemical analyses in the prospecting of iron ores. Krylov, G.V., Two forms of chance errors in analyzing prospecting assays. Bober, I.A. et al., On the possibility of making quantitative boron determinations in rocks by means of neutron-neutron logging. Bedrov, G.I., An experiment in geologic location operations in areas of rare-metal deposits. Shcherbov, D.P., A.I. Ivankova, I.T. Solov'yan and A.V. Drobachenko, Fluorescence analysis of inorganic substances. 1. A study of the fluorescent reaction of gallium with rhodamine S and 6 Zh. Shcherbov, D.P. and I.T. Solov'yan, 2. Fluorometric determination of gallium in ores by means of rhodamine S. Podberezskaya, N.K., The separation of lead from molybdenum by the cementation method. Dvorechenskiy, F.I. et al., An experiment in the application of the photo-neutron method of determining beryllium in ores.

15. Trudy Morskogo Gidrofizicheskogo Instituta Akad. Nauk SSSR. [Publications of the Marine Hydrophysical Institute of the Academy of Sciences of the USSR]: T. 16, Moscow, 1959, 174 pp. Partial contents: Lyubimova, Ye.M., The vertical distribution of organic phosphorus in the waters of the Black Sea. Lyubimova, Ye.M., Arsenic in the waters of the Black Sea.

16. Trudy Nauchno-Issledovatel'skogo Instituta Geologii Arktiki. [Publications of the Scientific Research Institute of Arctic Geology]: T. 98, Leningrad, 1959, 175 pp. Contents: Gramberg, I.S. and N.S. Spiro, An experiment in the utlization of geophysical data in the correlation and facies analysis of the Permian deposits of the Khatanga depression. Spiro, N.S. and N.S. Bonch-Osmolovskaya, The composition of the absorbed bases of clays in cases of equilibrium with waters of different types. Spiro, N.S. and Ts. L. Vovk, A reconstruction of the composition of the waters of the Permian sea. Spiro, N.S., I.S. Gramberg and Ts.L. Vovk, On the use of manganese in reconstructing the redox potential during the period of sedimentation. Vovk, Ts.L., The distribution of vanadium, nickel and chromium in sedimentary rocks of various ages. Spiro, N.S. and A.I. Danyushevskaya, A new method of comparative characterization of bitumens and oils based on their luminescence-capillary properties. Danyushevskaya, A.I., Chromatography of the hydrocarbons in the bitumen of the Sangar coal. Koteneva, T.V., The use of the colorimeter-turbidimeter in the analysis of readily soluble salts. Data on the chemical analyses of the Permian argillaceous rocks in the areas of Capes Tsvetkov and Nordvikskiy.

17. Trudy Soveshchaniya po Razrabotke Unifitsirovannoy Stratigraficheskoy Shkaly Tretichnykh Otlozheniy Krymsko-Kavkazskoy Oblasti. [Publications of the Conference on Elaborating a Unified Stratigraphic Scale for the Tertiary Deposits of the Crimea-Caucasus Region]: Baku, 1959, 314 pp. Contents: Nalivkin, D.V., On the chief tasks of the Conference. Davitashvili, L.Sh., On the ecogenesis of the fauna in the Upper Tertiary deposits of the Crimea-Caucasus region and its significance for the development of a unified stratigraphic scale for these deposits. Kacharava, I.V. and D.M. Khalilov, The stratigraphic subdivision of the Paleogene deposits of the Crimea-Caucasus region. Eberzin, A.G., The stratigraphic scheme of the Neogene deposits in the south of the USSR. Vyalov, O.S., The stratigraphic scheme of the Paleogene deposits of the European part of the USSR. Muratov, M.V. and G.I. Nemkov, The stratigraphy of the Paleogene deposits of the Crimea as a basis for the stratigraphic subdivision of the Paleogene in the Soviet Union. Alizade, K.A., The Tertiary deposits of Azerbaydzhan. Agalarova, D.A., The microfaunal subdivision of the Pliocene deposits of Southwestern Turkmenistan. Popov, G.I., The Apsheronian deposits of Southwestern Turkmenistan, Sarykamysh and the Krasnovodsk Peninsula. Dzhumagaliyev, T.N., The Tertiary deposits of the eastern part of Ural-Volga interstream area. Eventov, Ya.S., The stratigraphy of the Paleogene deposits in the western part of the Caspian depression. Vakhaniya, Ye.K., and D.A. Buleyshvili, The stratigraphy of the Tertiary deposits of Georgia. Gabrielyan, A.A. and N.A. Saakyan, The stratigraphic subdivision of the Tertiary deposits of Armenia. Nikitina, Yu.P., The Paleogene deposits of the Southern Emba region in the light of a study of the foraminifera. Grossgeym, V.A., The Paleogene deposits of the Western Kuban. Klyushnikov, M.N., The stratigraphy of the Paleogene deposits of the Ukrainian SSR. Vyalov, O.S., The Neogene deposits of the western areas of the Ukrainian SSR. Kudrin, L.N., The stratigraphy of the Miocene deposits of the Western Ukraine. Shutskaya, Ye.K., The stratigraphy of the Lower Paleogene in the Northern Caucasus, the Crimea and certain adjoining regions. Mamykin, S.S., The stratigraphic subdivision of the Tertiary deposits of Belorussia on the basis of a study of spore-pollen complexes. Mchedlishvili, P.A., The development of the Tertiary flora of the European part of the USSR and the Caucasus and its stratigraphic significance. Morozova, V.G., The zonal stratigraphy of the Paleogene, on the basis of the development of microscopic foraminifera. Mekhtieyev, Sh.F., and B.G. Bekilov, On the present state and future prospects of the investigations of the Tertiary deposits in the south of the European part of the USSR.

18. Trudy Ukrainskogo Nauchno-Issledovatel'skogo Instituta Solyanoy Promyshlennosti. [Publications of the Ukrainian Scientific Research Institute of the Salt Industry]: Vyp. 2(10), Moscow, 1959, 115 pp. Partial contents: Antipova, A.S., On the parallelism of the salt beds in the Artemovskiy and Slavyanskiy areas of the Donets Basin. Uzemblo, V.V., Salt deposits in the Lena part of the Olekma region of the Yakut ASSR. Bizin, V.D., The oil and gas contents of the Solotva brachyanticlinal structure of the Transcarpathian region of the Ukrainian SSR.

19. Trudy Tsentral'nogo Nauchno-Issledovatel'skogo Gornorazvedochnogo Instituta

"TSNIGRI". [Publications of the Scientific Research Institute of Mining and Prospecting "TSNIGRI"]: Vyp. 33, Moscow, 1959, 140 pp. Partial contents: Rogachev, B.V., Refraction-wave patterns over tectonic dislocations. Kudryavtseva, I.A. and V.V. Adrianov, Geophysical survey methods in the study of the gold-ore content and in geologic mapping in the Lena region.

Uchenyye Zapiski Azerbaydzhanskogo Universiteta, Geol.-Geogr. Ser. [Scientific Notes of the University of Azerbaydzhan, Geologic-Geographic Series]: No. 5, Baku, 1959, 82 pp. Partial contents: Abramovich, M.V. and Sh.F. Mekhtiyev, Some results of a study of the bitumens in the sedimentary rocks of Azerbaydzhan. Burchak-Abramovich, N.N., Speleology in the Rumanian People's Republic. Mustafabeyli, M.A., I.M. Liberzon and M. A. Aksel'rod, On the structure of the southern margin of the Kusar-Divicha synclinorium within the Khanaga area. Kasimova, G.K., Representatives of the family epistominidae from the Upper Aalenian stage in the Tairdzhal-Chay Samur region (Azerbaydzhan). Seidov, A.G. and D.I. Zul'fugarly, The petrographic and mineralogical characteristics and the contents of minor elements in the clays of the Maykopian suite in Azerbaydzhan. Maggeramova, F.S., On the tectonics of the deposits of the Apsheronian stage in the central part of the Apsheron Peninsula.

CHRONICLE

ON THE METALLOGENIC MAP OF THE U. S. S. R.[1]

by

G. F. Yakovlev

On November 25, 1959, in IGEM of the Academy of Sciences of the U. S. S. R., under the chairmanship of Academician D. I. Shcherbakov, was held the regular expanded meeting of the Interdepartmental Scientific Council on the Study of the Laws Governing the Location of Economic Minerals. This meeting was devoted to a consideration of the metallogenic map of the U. S. S. R. on the scale of 1:5,000,000 prepared by the All-Union Institute of Geology of the Ministry of Geology and Conservation of Mineral Resources of the U. S. S. R., with the participation of other geological organizations, and edited by V. G. Grushevoy, G. S. Labazin, A. I. Semenov, P. M. Tatarinov and others. The discussion, in addition to the members of the Scientific Council, also included representatives of the All-Union Institute of Geology, IGEM of the Academy of Sciences of the U. S. S. R., the State University of Moscow and other organizations.

In his introductory remarks Academician D. I. Shcherbakov commented upon the great importance of the metallogenic map of the U. S. S. R. on the scale 1:5,000,000 as a summarizing map required in the planning of ore prospects. This map is, in its way, the key and the basis for preparing detailed metallogenic prognostic maps of the individual ore provinces.

The main purpose of the meeting was to discuss the scientific principles and methods underlying the preparation of the first metallogenic map of such an enormous and extremely varied territory, both geologically and metallogenically, as is the Soviet Union. Such maps have never before been prepared either in the U. S. S. R. or in other countries.

[1]O metallogenicheskoy karte SSSR.

A report on the scientific principles and methods of preparing the metallogenic map of the U. S. S. R. was delivered by the representative of the All-Union Institute of Geology, A. I. Semenov, Doctor of Geological and Mineralogical Sciences.

The metallogenic map of the U. S. S. R. on the scale of 1:5,000,000 represents a generalization from an enormous amount of factual data, including the most recent, on the geologic structure, igneous activity and ore content of the territory of the U. S. S. R., and has been constructed on a geologic and tectonic base map.

In accordance with the recommendations of the Commission on the Study of the Laws Govern ing the Location of the Prinicpal Economic Minerals, the preparation of this map was guided by the principles of structural regionalization adopted for the "Tectonic Map of the U. S. S. R. and Adjoining Countries" on the scale of 1:5,000,000 (1956), edited by Academician N. S. Shatskiy. Use was also made of the "Geologic Map of the U. S. S. R." edited by Academician D. V. Nalivkin and of the latest geologic and metallogenic maps of the individual regions (the Caucasus, Central Asia, the Altay, Kazakhstan and others). In addition, information was derived from geophysical investigations (magnetic, gravimetric and others) and exploratory structural drilling on platforms and hidden folded regions.

The metallogenic map of the U. S. S. R. contains a detailed geotectonic regionalization. This shows: a) Precambrian mobile zones (areas of Precambrian folding); b) Paleozoic, Mesozoic and Cenozoic mobile zones (areas of Paleozoic, Mesozoic and Cenzoic folding); c) ancient platforms; d) Epipaleozoic and Epimesozoic platforms (platform mantle).

The Precambrian mobile zones are subdivided into: 1) Archean; 2) Archean reworked in the Proterozoic; 3) Proterozoic (undivided); 4) Lower Proterozoic and 5) Middle Proterozoic.

The Paleozoic, Mesozoic and Cenozoic mobile zones are subdivided into: 1) Proterozoic-Cambrian (regions of Baykalian folding), 2) Lower

d Middle Paleozoic (areas of Caledonian fold-g), 3) Middle and Upper Paleozoic (areas of ercynian folding), 4) Mesozoic (areas of Meso-ic folding), 5) Mesozoic-Cenozoic Mediter-nean and 6) Cenozoic Pacific Ocean regions. ithin these mobile zones are distinguished the sins of the initial, early and middle stages of e period of development of the geosyncline and s transition into a folded mobile zone, the in-rior basins and marginal basins of the late and rminal stages of the period of further develop-ent and consolidation of the folded zone, and so the subgeosynclinal superimposed struc-res.

In the tectonic zones the respective structural-rmational complexes are shown: terrigenous, rbonate, volcanogenic-sedimentary, terres-ial volcanogenic variegated or carbonaceous. here is also an indication of the continental posits of late basins, volcanogenic-sedimen-ry (platform) mantles of Paleozoic or Meso-ic age in the central massifs and projections Precambrian structures. In addition, the ap shows the formations of the cores of anti-inoria and the uplifted tectonic blocks of Pre-mbrian and Paleozoic age, as well as the Pre-mbrian or Paleozoic folded formations of the ntral massifs.

The ancient platforms (Russian and Siberian) e shown to contain five structural stages, mposed respectively of terrigenous, carbo-te, volcanogenic-carbonate and carbonaceous posits.

The Epipaleozoic and Epimesozoic platforms Vestern Siberian, Turan, Kolyma and Turgay) ntain structural stages or stratigraphic com-exes composed of terrigenous, marine or ntinental, carbonaceous and other deposits.

On the basis of geophysical investigations and ploratory structural drilling, the metallogenic ap has been made to show the structure con-ur lines of the basements of the ancient and pipaleozoic platforms, the supposed boundaries the first, second and third structural stages the platform mantle of ancient platforms, d the first stratigraphic complex in the mantle the Epipaleozoic Western Siberian platform.

Intrusive complexes are distinguished ac-rding to the geotectonic conditions of their rmation, their age and their composition. ne geotectonic conditions distinguish the in-usive rocks of various periods of formation folded regions (initial and early, middle, te and terminal stages of development) and atforms. In addition, the intrusives have en noted whose age and geotectonic conditions formation are not known. Among the intru-ve rocks of folded regions, Archean grani-ids, Archean hyperbasites and Proterozoic anitoids (undivided) are shown.

The groups of intrusive complexes have been subdivided in detail by age. In the folded regions are shown: Proterozoic, Upper Proterozoic—Lower Cambrian (Baykalian), Lower and Middle Paleozoic (Caledonian), Middle and Upper Paleozoic (Hercynian), Mesozoic and Cenozoic. On the basis of their composition, the following groups of complexes are indicated: 1) hyperbasite, 2) peridotite-gabbro, 3) gabbrodiorite-plagiogranite and gabbrodiorite-granosyenite (derivatives of basic magma), 4) primarily batholithic intrusives of moderately acidic granitoids (derivatives of granitic magma), 5) primarily batholithic intrusives of acidic and hyperacidic granites, 6) granitoids of varied composition and partly rocks of intermediate and basic composition (chiefly minor intrusives), 7) alkaline and subalkaline intrusives, 8) trap-rock intrusives.

The intrusive rocks of platforms are divided by age into Proterozoic, Paleozoic and Mesozoic. According to their composition they are shown as: 1) ultrabasic and basic intrusives, 2) kimberlites, 3) ultrabasic alkaline intrusives with carbonatites and 4) alkaline intrusives. In addition, trap-rocks of Paleozoic and Mesozoic age are shown separately.

The intrusives whose geotectonic conditions of formation or whose age are unknown are divided by composition into the categories of anorthositic and granitoid.

The map also shows faults, which are subdivided into: 1) deep faults (known and inferred), 2) faults in the basements of platforms and 3) principal normal faults and thrusts. Active and extinct volcanoes are also shown. The specific sedimentary-volcanogenic, terrigenous and metamorphic formations are shown in the case of the Ukrainian, Baltic and Anabar shields. For the area of the Western Siberian Epipaleozoic platform, there are superimposed sections derived from exploratory structural drilling data.

The economic minerals (the principal ones) are subdivided into genetic groups: magmatic proper, pegmatitic, skarn, hydrothermal, telethermal, metamorphogenic and exogenic, and those of unknown genesis. According to the geotectonic conditions of their formation, the deposits are divided into: 1) those of mobile zones (a - initial and early, b - middle, c - late and terminal stages of development), 2) those of platforms and 3) those of unknown geotectonic conditions.

Thus the principles upon which the metallogenic map of the U. S. S. R. is based take account of the chief stages in the historical development of platforms and mobile zones: the pre-Paleozoic, Baykalian, Caledonian, Hercynian, Mesozoic and Cenozoic stages of development of the earth's crust. There is also an

indication of the interrelationship between sedimentation, tectonics, igneous activity and ore mineralization, not only in time, but also in space. The latter has been achieved by the distinguishing detailed tectonic structures both on platforms and in geosynclinal zones.

On the basis of an analysis of a large amount of geologic and metallogenic data, the authors of this map have distinguished five structural-metallogenic zones, including areas of actual known and possible distribution of exogenic mineralization in the platform mantle: 1) primarily initial and early stages, 2) primarily middle stages, 3) primarily late and terminal stages, 4) various stages of development of mobile zones, 5) platform mineralization. Figures in the contours of the structural-metallogenic zones show the predominant geologic age of the mineralization and the characteristic associations of economic minerals determining the metallogenic type to which the zones belong.

On the basis of an analysis of all the available data on the geologic structure, igneous activity and ore content of the territory of the U.S.S.R., the structural-metallogenic zones and ore-bearing regions have been distinguished. These zones and areas reflect not only the actual location of economic minerals, but also their possible distribution – that is, they contain the elements of geologic forecasting of the occurrence of new deposits of economic minerals. The latter may be used in the planning of prospecting operations.

Academician D.I. Shcherbakov, Corresponding Member of the Academy of Sciences of the U.S.S.R., V.I. Smirnov, Doctor of Geological and Mineralogical Sciences, Yu.A. Arapov, G. A. Sokolov, Ye.T. Shatalov and Yu.M. Sheynmann took part in the discussion. All the participants remarked that this metallogenic map of the U.S.S.R. on the scale of 1:5,000,000 is a major achievement of Soviet geologic science in the area of metallogenic investigation. The basic scientific principles and methods underlying the preparation of this map have been chosen correctly and may therefore be used in the preparation of similar maps.

Nevertheless a few defects were noted, which are quite natural in a first attempt at such a task:

1) insufficient clarity of the metallogenic information shown on the map;

2) stages of ore mineralization and structural-metallogenic zones are shown, but there is no indication of metallogenic epochs corresponding to the indicated epochs of sedimentation, formation of tectonic structures and igneous activity, and the types of metallogenic provinces; thus it is desirable to prepare additional structural-metallogenic diagrams for this purpose; there is no subdivision of the exogenic deposits;

3) the boundaries and the times of formation of certain structural-metallogenic zones (for example, the Altay and the Caucasus) are not sufficiently based on metallogenic facts and are still controversial. Thus it would be desirable to distinguish structural-metallogenic zones containing mineralization whose connection with particular stages of development of a mobile zone is not clear.

The Scientific Council on the Study of the Laws Governing the Location of Economic Minerals adopted a resolution approving the scientific principles used as the basis for the first metallogenic map of the U.S.S.R. on the scale of 1:5,000,000 and the methods of its preparation.

There is no doubt that the metallogenic map of the U.S.S.R. on the scale of 1:5,000,000 is a great step forward in geologic science and confirms the pre-eminent position of Soviet geologists in the field of metallogenic mapping.

IN MEMORY OF ACADEMICIAN F. Yu. LEVINSON-LESSING[2]

by

S.V. Yefremova

On December 24, 1959 there was a meeting of the Petrographic group of the Institute for the Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the Academy of Sciences of the U.S.S.R., in honor of the twentieth anniversary of the death of Academician Frants Yul'yevich Levinson-Lessing.

Recollections of F.Yu. Levinson-Lessing and reports on the development of his ideas were presented by Doctor of Geological and Mineralogical Sciences Ye.K. Ustiyev, Academician D.I. Shcherbakov, Corresponding Member of the Academy of Sciences of the U.S.S.R. G.D. Afanas'yev and Doctor of Geological and Mineralogical Sciences N.I. Khitarov.

Ye.K. Ustiyev noted that Levinson-Lessing's creative activity followed three directions which have had the greatest effect on the development of modern petrography. Each of these alone would have been enough reason for considering h[im] one of the fathers of "world and Soviet petrography".

The first of these is the chemical (and later physicochemical) aspect of petrography, which was begun by Levinson-Lessing's work on the

[2]Pamyati Akademika F.Yu. Levinson-Lessinga.

mical classification of igneous rocks, pub-
ıed in the last decade of the XIX Century.
s work defined the framework and noted the
ic subdivisions of the present classification
gneous rocks, based upon their chemistry.
; sufficient to say that this was the first
division of rocks into "acidic", "intermed-
" and "basic", and the first formulation
ational principles of such subdivisions based
on the absolute content of silicic acids, but
n the degree of their saturation with bases.

The report described the great influence of
work by F. Yu. Levinson-Lessing upon
ld petrography, elevating it from the im-
se of "Rozenbushism" (the physiographic
ection in petrography) to a higher level of
elopment.

The second important aspect of Levinson-
sing's creative activity was his work on the
blems of magma. He provided thorough-
ng solution to these problems, which were
ery great importance for the development
nodern conceptions of the nature and origin
nagmatic melts. For example, in full agree-
nt with the views expressed half a century
by Levinson-Lessing, we now speak of
saltic" and "granitic" magmas.

In recent years F. Yu. Levinson-Lessing
ieved it very likely that there are ultrabasic
lts independent of basic magma, and also
ote on the impossibility of explaining certain
s without the conception of a "migma". It
clear from this that even in the early stages
iis activity he stood closer to our modern
ceptions of magma than, for example, such
iis theoretical oponents as N. Bowen or R.
y.

The third aspect of F. Yu. Levinson-Lessing's
k embraced a number of problems associ-
d with the reasons for the great variety of
eous rocks. In this difficult area of know-
ge he was also ahead of his time, and had a
at influence on the general development of
rography. It was typical that he very early
ied the hypothesis of universalism and at-
pted to see the causes of the variety of
npositions of rocks in processes of complex
ure.

Along with all the various forms taken by the
cesses of differentiation, he repeatedly de-
ibed the evidence indicating mixtures of
lts and the phenomena of remelting (syn-
tics), assimilation, contamination and hy-
lism. He attributed great importance to
ingenesis and selective melting in the for-
tion of acidic rocks.

A particularly striking example of his scien-
c intuition is his views on the problem of
immiscibility of magmatic melts. As early
1884 he described clear indications of liquation in the variolites of Yalguba, and thereafter elaborated his "syntectic-liquational" theory of differentiation. Only very recently have experiments with silicate melts and containing large amounts of volatiles indicated the actual possibility of achieving immiscible liquids under conditions close to those in nature. This aspect of Levinson-Lessing's activity very clearly shows the breadth and daring of his scientific thinking and the proper importance which he always attached to field investigation in geology. "Every petrographer must first of all be a geologist"—this is the principle which in the fifty-year controversy over liquation finally won an overwhelmingly victory!

D. I. Shcherbakov stressed the fact that F. Yu. Levinson-Lessing belonged to the constellation of outstanding geologists at the end of the XIX and beginning of the XX centuries who were distinguished for their universal knowledge. His work encompassed an unusually great range: from the history of science to paleontology, dynamic and historical geology, the study of ore deposits, mineralogy and from volcanology to soil science and petrography, which he loved most of all. With this breadth of interests, he was able to develop a number of trends in science, many of which still exist at present. For example, he pursued the experimental tendency in petrography, the investigation of the physical properties of rocks and minerals and geochemical work. He was a founder of the Kamchatka Volcanological Station. In his investigations Frants Yul'yevich was also no stranger to problems of the philosophy of the natural science, and showed a great tendency toward philosophical generalization. Thus, F. Yu. Levinson-Lessing has left a great heritage of his original ideas.

He taught us the value of a proper appreciation of pioneering scientists and of a toleration of various scientific views. He inculcated in us a love for the popularization of science and for the discussion of scientific problems by the masses. He taught us to associate our scientific interests with the requirements of life.

G. D. Afanas'yev briefly discussed the chief trends in Soviet petrography during the past twenty years. He also remarked on the important and useful role played by the Academy of Sciences of the U. S. S. R. in the coordination of petrographic work done in the last two decades within the U. S. S. R., and set forth certain of the problems associated with the study of the earth's crust.

In his opinion, the most important problems of modern petrography are:

1) The study of the igneous activity in the earth's crust in relation to its deep structure. A very important aspect of this problem is the

correct petrographic interpretation of the geophysical data on the structure of the earth's crust, since in this field hypothetical views have come forth which contradict the data of igneous geology. A knowledge of the deep structure of the earth's crust and of the ocean bottoms of this planet, upon which mankind lives and works, is one of the most important goals of modern science, whose importance is equal to that of conquering space and at the present time involves the combined efforts of geophysicists, geologists, petrographers and specialists in other related sciences.

2) The further development of isotope geology; this involves radio-geologic investigations of igneous and metamorphic rocks, as well as determination of the absolute ages of rocks and igneous complexes.

Investigations in this field will facilitate the discovery of; a) the laws governing the paragenesis of natural associations of rocks; b) the petrogenetic relationships of intrusive, extrusive and vein rocks; c) the periodicity of magmatic processes in the earth's crust; d) the specific material composition of magmatic complexes of various ages and the metallogeny associated with them as a basis for creating hypotheses on the geochemical and petrographic epochs in the earth's history.

N. I. Khitarov briefly described the basic problems of igneous activity, for the solution of which F. Yu. Levinson-Lessing constantly, and in many cases successfully, carried out experiments.

Most of his report was devoted to experimental investigations of a number of problems associated with the major problem of magma which the author of the report himself had studied.

He demonstrated the established quantitative characteristics of the relationships of the gaseous components and water to the granitic and basaltic melts. For example, the 900° and 1000° isotherms are characterized by lower solubility of water in a melt of basic composition, although it is not impossible that the water solubilities become equal in both melts in the region of higher temperatures, in spite of the differences in their chemical composition.

He remarked on the high crystallizational capability of a basaltic melt with the formation of a large amount of hornblende when water is present in amounts exceeding its content in the original basalt. The curves for the solubility of water in basaltic and granitic melts suggests the conclusion that, under isothermal conditions, as the magma moves into the upper structural stages (regions with lower pressures), a basaltic magma will tend to throw the greater part of the water dissolved in it into the deeper layers. In the case of a granitic magma one expects the opposite behavior: the water dissolved in it will be separated out and ejected primarily into the upper structural stages of the earth's crust. These data are of great significance for the theory of ore-forming solutions.

A series of special experiments on the relationship of basalt and granite to water under dynamic conditions, at pressures of 600 and 3000 atm, have enabled N. N. Khitarov to throw some light on the problem of the existence of juvenile water, and also to prove the material transformation of the original rocks into a series of more acidic differentiates, in which the evolution of the original material in the presence of water has depended on a number of factors, including the time of the reaction.

In general, the meeting showed the progressive nature of F. Yu. Levinson-Lessing's ideas. Some of these ideas, as before, must still be resolved, whereas others have been fruitfully developed in the work of the Soviet school of petrographers, whose acknowledged leader and coryphaeus was Academician Frants Yul'yevich Levinson-Lessing.

IN THE COMMITTEE ON SEDIMENTARY ROCKS OF THE DIVISION OF GEOLOGIC AND GEOGRAPHICAL SCIENCES OF THE ACADEMY OF SCIENCES OF THE U. S. S. R.[3]

by

V. S. Yablokov,

Acting President of the Committee

I. Coordination Meeting

On February 3 - 5, 1960, a coordination meeting was held on the problem of the stages in rock formation. Eleven reports were heard and discussed on the results of work done on various subjects related to this problem and carried out in various organizations: 1) by V. D. Shutov (GIN of the Academy of Sciences of the U. S. S. R.) - "On the Epigenetic Alterations of the Lower Paleozoic Rocks on the Southeastern Margin of the Russian Platform"; 2) by A. V. Kopeliovich (GIN Academy of Sciences U. S. S. R.) - "On the Epigenetic Alteration of the Lower Paleozoic Rocks on the Southwestern Margin of the Russian Platform"; 3) by A. G. Kossovskaya (GIN Academy of Sciences U. S. S. R.) - "Some Features of Epigenesis on Platforms and in Geosynclines"; 4) by A. S. Zaporozhtseva (NIIGA) - "On the Relationship

---

[3]V Komissii po osadochnym porodam pri Otdelenii Geologo-Geograficheskikh Nauk Akad. Nauk, SSSR.

ıe Processes of Diagenetic Change to the ies Conditions of Sedimentation"; 5) by M. Veselovskaya, Z.P. Ivanova and A.A. Klev- a (VNIIGNI) - "On the Stages of Formation ıe pre-Devonian Deposits in the Central and tern Regions of the Russian Platform"; 6) 'u. A. Khodak (SOPS) - "Stages in the For- ion of the Ancient Sedimentary Strata of the et Far East and the Adjoining Territories"; y N.A. Lizalek (SNIIGGIMS) - "Secondary rations of the Devonian Deposits of the hern Minusinsk Basin"; 8) by V.S. Vasil'- (NIIgeol. of the University of Saratov) - ges in the Development of the Authigenic cic Formations in the Mesozoic and Cenozoic ks in the Lower Povolzh'ye Region"; 9) by . Perozio (SINIIGGIMS) - "On the Epigenetic nges in the Mesozoic Rocks of the Narim a of the Ob' River Region"; 10) by T.M. ova (SNIIGGIMS) - "Processes of Secondary eral Formation in the Mesozoic Deposits of Western Siberian Lowland"; 11) by G.N. vkov (IGGSOAN) - "The Main Features of Diagenesis of the Coal-bearing Aalenian osits of Dagestan". N.M. Strakhov (Presi- of the Committee) read a general report on problems and methods of further investiga- s.

epresentatives from 31 organizations from cow, Leningrad, Kiev, Riga, Tashkent, osibirsk, Krasnoyarsk, Buguruslan, Syktyv- Saratov and other cities participated in meeting.

'he meeting adopted the following resolution:

. To note that the study of the stages of c formation, which has begun and expanded ecent years, is of great theoretical impor- e for the correct description of rocks and rmination of the conditions of their forma- , and also of practical value in discovering laws governing the formation and distribu- of a number of economic minerals (sedi- tary ores, oil and gas).

. To acknowledge the need for expanding program of investigations and, in addition etailed mineralogical and petrographic ies, for determining the physical and me- ıical properties of rocks (density, porosity,); for studying the composition of the inter- al waters in rocks, as well as that of ground ers and the transformations of organic mat- and to aim not only for qualitative, but also quantitative determinations of the various eria.

. To acknowledge the value of detailed in- igations of sections (in test wells) from top ottom, taking account of the facies condi- s and the composition of the deposits.

. To recommend that a high priority be n to the study of platform sections (the Russian platform, the Western Siberian Low- land, etc.).

5. To devote special attention to organiza- tions active in the study of sections in a number of oil regions, as well as of core samples of marine deposits, in order to determine the characteristics of the early stages of epigenesis.

6. To recommend that the leading institutions in lithologic investigations, along with their stratigraphic surveys and documentation of test wells, set aside for special emphasis the pro- blems associated with the stages of rock for- mation as a separate branch of study, with its own specific tasks.

7. To request all organizations concerned in the problem of the stages of rock formation to transmit to the Committee on Sedimentary Rocks information on the subjects being devel- oped, in connection with the preparation of a general plan for the work on this general pro- blem.

The experience of the meeting confirmed the opinion of the Committee, approved by the Bureau of the Division of Geological and Geo- graphic Sciences of the Academy of Sciences of the U.S.S.R., that the Committee should not undertake the general coordination of all the investigations of sedimentary rocks or pre- pare general plans for the work of all the in- stitutions, but should merely hold meetings con- fined to the basic and currently most important problems.

The familiarization of workers in this field with the methods of investigation and the scien- tific results achieved in various subjects and the corresponding conclusions, is, in essence, the coordination of investigations.

II. Work Plan of the Committee for 1960

It was decided to organize two more meetings, in addition to the meeting that was held on the stages of rock formation. The first will be held on May 24-27, 1960, on the subject of the forma- tion of modern marine sediments, at which the reports will be grouped in four sections: 1) the transport of sedimentary material into bodies of water, 2) sedimentation in seas, 3) sedimen- tation in oceans and 4) the diagenesis of marine deposits.

It was decided to hear approximately twenty- five reports by representatives of the following institutes: Oceanology, Arctic Geology, VNIGNI, Hydrophysics, Geology, VNIIO, and others.

In December, 1960, a meeting will be held to exchange experiences in the application of the most recent physical methods to the study of sedimentary rocks. This meeting is to hear reports on concrete problems of the utilization

of various kinds of equipment, its practical application and the results of investigations.

Applications for reports to be delivered should be sent to the Committee before October 1 (Moscow, V-17, Pyzhevskiy Pereulok, 7, GIN Acad. Sci. U.S.S.R.), whereupon the final decisions will be made in regard to the participants at the meeting, the adgenda and the duration.

The Committee is preparing two collections of articles for print: the main reports on formations delivered at the Fourth Lithologic Conference at Tashkent in 1959 and reports delivered at the Conference on Modern Marine Sedimentation.

The Committee has transmitted the results of discussions and observations on the project of classification of various types of sedimentary rocks, which were sent in 1958 to a large number of persons and geological institutions.

It has appeared that the suggested classification of different rocks cannot be recommended without important corrections. It has been recognized that before developing particular classifications, certain general principles should be worked out for the classification of sedimentary rocks according to their composition, structure and texture, and that problems of taxonomy and terminology should be more precisely defined. The materials on these problems are in the stage of preparation and preliminary discussion.

Work has begun in the preparation for the Fifth Lithologic Conference, which is to be held in the summer of 1961 at Novosibirsk. The subjects of the meeting will be in two groups: 1) methods and experience of preparing litholog facies and paleogeographic maps of various typ in the U.S.S.R., and 2) the lithology of the sed mentary formations of Western Siberia.

GENERAL ASSEMBLY OF THE DIVISION OF GEOLOGIC AND GEOGRAPHIC SCIENCES OF THE ACADEMY OF SCIENCES OF THE U.S.S.R. ON THE OCCASION OF THE NINTIETH ANNIVERSARY OF THE BIRTH OF V.I. LENIN [4]

On April 14, 1960 there was a general assem bly of the division of Geologic and Geographic Sciences of the Academy of Sciences of the U.S.S.R. in honor of the founder of the Soviet State, Vladimir Il'ich Lenin, on the occasion of the 90-th anniversary of his birth.

After the introductory words by Academicia D.I. Shcherbakov, Secretary of the Division, Professor D.I. Gordeyev presented a report on "V.I. Lenin and Geology".

Thereafter the following reports were heard

by Corresponding Member of the Academy o Sciences of the U.S.S.R. L.A. Zenkevich, on V.I. Lenin's decree initiating complex oceanological investigations in the U.S.S.R.;

by Professor P.M. Alampiyev, on Lenin's ideas on socialist economic regionalization and their practical realization.

[4] Obshcheye Sobraniye Otdeleniya Geologo-Geograficheskikh Nauk Akad. Nauk SSSR, posvyashchennoye 90-Letiyu so dnya rozhdeniya V.I. Lenina